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By G.V. Urata and J.O. Franchi

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25-kVA AMORPHOUS METAL-CORE TRANSFORMER DEVELOPMENTAL TEST REPORT

ABSTRACT NCEL has completed a test and evaluation program for 25-kVA amorphous metal-core transformers. These transformers save energy by reducing no-load losses by 60 to 70 percent. No-load losses are estimated to cost the Navy millions annually and if all of the Navy transformers were replaced by amorphous metal-core transformers, the Navy would save millions a year. The program objective was to evaluate the electrical performance and operational reliability of the amorphous metal-core transformers compared to conventional silicon-steel transformers.

NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043-5003

METRIC CONVERSION FACTORS

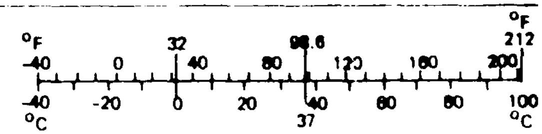
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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G.V. Urata, P.E. and J.O. Franchi

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NCEL has completed a test and evaluation program for 25-kVA amorphous metal-core transformers. These transformers save energy by reducing no-load losses by 60 to 70 percent. No-load losses are estimated to cost the Navy millions annually and if all of the Navy transformers were replaced by amorphous metal-core transformers, the Navy would save millions a year. The program objective was to evaluate the electrical performance and operational reliability of the amorphous metal-core transformers compared to conventional silicon-steel transformers.

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INTRODUCTION

The Naval Civil Engineering Laboratory (NCEL) has completed a test and evaluation program for 25-kVA amorphous metal-core transformers. Amorphous metal-core transformers save energy by reducing transformer no-load losses by 60 to 70 percent. No-load losses are the power required to energize the transformer core and are constant regardless of the load on the transformer. No-load losses cost the Navy millions of dollars annually. The Navy operates approximately 79,000 liquid-filled distribution transformers at 150 locations. If all of the Navy transformers were replaced by amorphous metal-core transformers, the Navy would save millions a year. The program objective was to evaluate the electrical performance and operational reliability of the amorphous metal-core transformers compared to conventional silicon-steel transformers. The test and evaluation program was conducted in the following two phases.

Phase I

In Phase I, the electrical and mechanical performance of three General Electric 25-kVA amorphous metal-core transformers was compared with the electrical performance of two General Electric 25-kVA conventional silicon-steel transformers. The testing for this phase was conducted by Westinghouse Electric Corporation using American National Standards Institute (ANSI) and National Electric Manufacturers Association (NEMA) standards, at the Westinghouse Distribution Transformer Division plant, Athens, Georgia.

Phase II

In Phase II, electrical tests, overland transportation tests, and autopsies were conducted by General Electric on five 25-kVA amorphous metal-core transformers. An NCEL devised 3-foot drop test and autopsy was then conducted on three of the transformers. The laboratory testing for this phase was conducted using ANSI and NEMA standards, at the General Electric Distribution Transformer Division plant, Hickory, North Carolina.

BACKGROUND

Amorphous metals are an entirely new class of metallic material whose dominant characteristic is a lack of grain structure. In the process of producing amorphous metals, a proprietary molten alloy of iron, boron, and silicon is cooled rapidly at a rate of about 1 million °C per second so that crystals cannot form. Instead, the constituent atoms arrange themselves in a random fashion, rather than in the crystal lattices found in typical metals. The practical result of this process

is a material that, when used in the core of a transformer, reduces no-load losses to about 30 percent of those in a conventional silicon-steel transformer.

The reliability and performance of amorphous metal-core transformers are expected to be comparable to conventional silicon-steel transformers because virtually no changes have been made in the coil and insulation system. The only difference is the substitution of the more efficient amorphous metal-core material.

PHASE I TESTS

Four types of transformer tests were conducted in Phase I, including the typical commercial, design, ANSI/IEEE C57.12.90-1980 tests, and several additional tests designed by NCEL engineers. The identity, objective, and pass/fail criteria for the Phase I tests are described in the following paragraphs.

Commercial Tests

The commercial tests were performed: (1) to determine the transformer's electrical performance parameters upon initial receipt before testing, (2) to demonstrate compliance with nameplate data or contractual agreements, and (3) to identify any significant changes in transformer performance characteristics after the transformers were subjected to individual stressful tests. For the amorphous metal-core and silicon-steel transformers examined, the tests consisted of the following:

Ratio Test.

- Objective: The turns ratio of the transformer is the ratio of turns in the high-voltage winding to turns in the low-voltage winding. The objective of the ratio test was to demonstrate that the ratio of turns in the high-voltage and low-voltage windings was correct, so that a given impressed high voltage would produce the expected low voltage, according to the ratio of high-voltage winding turns to low-voltage turns.

- Pass/Fail Criteria: The observed ratio of high voltage to low voltage had to be within 0.5 percent of the transformer nameplate markings.

Polarity Test.

- Objective: The objective of the polarity test was to demonstrate that the leads and polarity marks on the transformer reflected the actual arrangement of the transformer windings. These data are particularly important when two or more transformers are operated in parallel.

- Pass/Fail Criteria: The polarities of the winding leads, as determined from testing, had to match the polarities shown on the nameplate.

Applied Voltage Tests.

- Objective: The objective of the applied voltage tests was to stress the major components of insulation, and the major insulation between the windings and ground. Two types of applied voltage tests were made: High-to-Low-to-Iron-to-Case (HLIC) applied voltage tests, and Low-to-High-to-Iron-to-Case (LHIC) applied voltage tests. In the HLIC tests, the test voltage was applied to the high-voltage transformer bushings (which were tied together), and the low-voltage bushings, which were tied together and grounded. In the LHIC tests, all low-voltage bushings were tied together and connected to the source voltage, and the high-voltage bushings wee tied together and grounded. The HLIC tests stressed the insulation of the high-voltage windings. TheLHIC tests stressed the low-voltage windings.

- Pass/Fail Criteria: There had to be no evidence of arcing, smoke, bubbles, or a sudden increase in test circuit current as a result of the applied potential. If such evidence existed, then troubleshooting was required to locate the source of the problem.

Induced Potential Test.

- Objective: The objective of the induced potential test was to stress interwinding insulation structures, as well as portions of the major insulation. The test applied greater than rated volts per turn to the transformer, so that it was run at higher frequency (400 Hz in this case) to avoid core saturation.

- Pass/Fail Criteria: There shall be no evidence of arcing, smoke, bubbles, or a sudden increase in test circuit current as a result of applied potential. If such evidence exists, then troubleshooting is required to locate the source of the problem.

No-Load Loss/Exciting Current Test.

- Objectives: The objectives of the no-load loss and excitation current tests were to determine: (1) the power loss in the transformer when operating at rated voltage and frequency, but not supplying load; and (2) the excitation current required to maintain the magnetic flux excitation in the transformer core. No-load losses include core loss, dielectric loss, and loss in the windings due to exciting current. Both no-load losses and excitation currents should be determined using sinusoidal sources, or by correcting for the applied source waveforms as described in Section 8 of ANSI/IEEE C57.12.90-1980.

- Pass/Fail Criteria: Not applicable because measurements are made and recorded per Section 8 of ANSI/IEEE C57.12.90-1980.

Design Tests

The design tests were performed to compare the amorphous metal-core transformers and the silicon-steel transformers with respect to adequacy of the design of their component parts, ability to meet assigned ratings, and performance under normal operating conditions. The tests consisted of the following:

Full-Wave and Chopped-Wave Impulse-Voltage Tests.

- Objective: The objective of the impulse-voltage tests was to determine the ability of the transformer to withstand lightning surges. Voltage waves with a nominal front of 1.5 microseconds and a nominal tail to half value of 40 microseconds were applied to each terminal of an unenergized transformer. The first applied wave was a reduced full wave whose crest value was 50 percent of the transformer's basic insulation level (BIL). This was followed by two chopped waves of 115 percent of the BIL. Chopping was accomplished by using a rod gap in air, adjusted to arc after the crest of the voltage wave. The chopped-wave applications were followed by a full wave at 100 percent of the BIL. The chopped wave stressed insulation between turns near the line end. The full wave stressed insulation between the middle of the winding and ground. Oscillograms were obtained for applied voltage versus time, and for neutral current versus time.

- Pass/Fail Criteria: Agreement in voltage and current wave shape between the initial full-wave reduced voltage application and the final 100 percent full-wave application indicated that the transformer had passed without damage. Any unexplainable difference in wave shape indicated a failure in either the windings, the major or minor insulation, or the bushings.

NOTE

In order to provide additional assurance that the amorphous metal-core transformers would withstand lightning surges, the tests were performed on an energized transformer, and additional stress tests were added to the test sequence. The test sequence included (in the following order): reduced full-wave test, chopped-wave test, 400-Hz induced potential test, front-of-wave impulse test (voltage wave is chopped before it crests), 400-Hz induced potential test, full-wave test, 400-Hz induced potential test, and HLIC and LHIC applied voltage tests.

Winding Resistance Test.

- Objective: The objective of the winding resistance test was to obtain winding resistance data that will be used later: (1) to calculate the I^2R component of conductor losses, (2) to calculate winding temperatures at the end of a temperature rise test, and (3) to use as a base for assessing possible damage in field operation. The winding resistance test was performed using the procedures in Section 5 of ANSI/IEEE C57.12.90-1980.

- Pass/Fail Criteria: Not applicable. Readings were taken, calculations were made to correct for the desired temperature at which the resistance values were to be used, and the data were applied as required.

Impedance Voltage/Load Loss Tests.

- Objective: The objective of the impedance voltage/load loss tests was to determine the voltage required to circulate the rated current under short-circuit conditions, and the associated watt loss when the source was connected to the rated voltage taps. The impedance voltage consisted of an effective resistance component corresponding to the load losses and a reactive component corresponding to the leakage flux linkages of the windings.

- Pass/Fail Criteria: Not applicable. Measurements were made per Section 9.2.2 of ANSI/IEEE C57.12.90-1980, and calculations of the impedance voltage and load loss watts were made per Section 9.4 of ANSI/IEEE C57.12.90-1980. For these tests, comparisons were made between the performance of the amorphous metal-core transformers and the silicon-steel transformers.

Temperature Rise Test.

- Objective: The objective of the temperature rise test was to determine the maximum temperature rise (above the ambient temperature) of the windings and the insulating fluid in the transformer when the transformer was operated at maximum kVA rating. The temperature rise test was conducted in accordance with the procedures in Section 11 of ANSI/IEEE C57.12.90-1980.

- Pass/Fail Criteria: The average winding and fluid temperature rise above ambient temperature could not exceed 65 °C or the temperature rise specified on the transformer nameplate (whichever is smaller). The winding hottest spot temperature could not exceed 80 °C

Audible Sound Level Test.

- Objective: The objective of the audible sound level test was to determine the audible sound emitted from the transformer when operated at rated voltage and frequency, and no load. Sound level measurements were significant because excessive sounds from transformers can be an annoyance in residential or other populated areas. Also, excessive sound levels may indicate apparent problems in the transformer core, such as loose or fractured core laminations. A sound level meter with an A-weighting frequency network was used for the measurements, since this type of weighting best represents the ability of a remote listener, with normal hearing, to hear the complex sounds generated by the transformer. The tests were conducted in accordance with the procedures in Section 13 of ANSI/IEEE C57.12.90-1980.

- Pass/Fail Criteria: The measured value of the A-weighted (A) sound level had to be no greater than 48 dB (A).

Radio Influence Voltage (RIV) Test.

- Objective: The objective of the RIV test was to determine the amount of RIV produced by the corona (local overstress) in transformer insulation. RIV, as the name implies, may cause interference to radio communications. Excessive corona also may be an indication of insulation breakdown. The tests were performed with the methods prescribed in NEMA Publication TR 1. Tests were run at 100 percent and 110 percent of rated voltage.

- Pass/Fail Criteria: NEMA Publication TR 1 lists limiting RIV values at about 110 percent of the operating voltage.

Short-Circuit Test.

- Objective: The objective of the short-circuit test was to demonstrate the ability of the transformer to withstand the stresses resulting from a short circuit applied to the transformer's primary or secondary terminals. The tests were conducted by either closing a breaker at the faulted terminal to apply a short circuit to a previously energized transformer, or by closing a breaker at the source terminal to apply energy to a previously short-circuited transformer.

- Pass/Fail Criteria: The impedance change shall be less than 11.1 percent, and the excitation current change shall be less than 25 percent, when a short-circuit current of 40 times the rated current is applied in accordance with the procedures of Section 12 of ANSI/IEEE C57.12.90-1980. There shall be no discernible damage to the transformer, based on a post-test autopsy.

Additional NCEL Tests

Safe Transit Tests.

- Objective: The objective of the safe transit tests was to demonstrate that the transformer could withstand the shocks and vibrations encountered on a cross-country shipment, with no significant mechanical damage, and no significant change in electrical performance characteristics. The tests consisted of: (1) a 4-hour test on the safe transit machine at 160 rpm to simulate two cross-country shipments by truck; and (2) a 4-foot drop of the transformer onto a hard surface (to simulate inadvertent mishandling during transit). Upon completion of the shake and drop tests, the transformer was subjected to the commercial tests to detect any changes in electrical performance; and to an autopsy, in which the transformer core was removed from the tank and inspected for damage.

- Pass/Fail Criteria: The commercial tests had to be passed satisfactorily, after completion of the safe transit tests, with no more than a 10 percent increase in measured no-load watts. There had to be no evidence of damage that would impair proper long-term, reliable operation of the transformer.

Infrared Scanning Test (Transformer Energized).

- Objective: The objective of the infrared scanning tests was to obtain (by means of an infrared-sensitive detector) a visual indication of the amount of energy required to magnetize the transformer core. In these tests, the infrared scans of the energized amorphous metal-core and silicon-steel transformers were compared.

- Pass/Fail Criteria: No quantified criteria. The intensity of the infrared radiation from an amorphous metal-core transformer had to be less than the infrared radiation from a silicon-steel transformer of the same rating when the transformers were operated under the same conditions.

Cold-Load Pickup Test.

- Objective: The objective of the cold-load pickup test was to determine whether heavy loading of a cold transformer had any injurious effects, such as thermal instability, on the transformer. The principal concern was that the transformer fluid could become so viscous at low temperatures that it could not circulate and transfer heat generated in the core and windings. This could create hot spots that could cause breakdown of the insulation and possible short circuits. For this test, the following conditions were assumed and simulated:

  - A power outage occured in a cold (-35 °C) environment.
  - A replacement transformer was obtained from a cold (-35 °C) environment and placed in service.
  - Upon restoration of service, a 200 percent rated load was placed on the transformer for the first 2 hours. This was followed by a 100 percent rated load for the next 6 hours.

Instrumentation was installed and measurements were made as prescribed in Section 9.2.2 of ANSI/IEEE C57.12.90-1980.

- Pass/Fail Criteria: There had to be no significant change in winding current during operation at 100 percent rated load or 200-percent rated load. Any such change was evidence of a potential failure that had to be investigated by an autopsy.

Saturation, Regulation, and Efficiency Tests.

- Objective: The objective of these tests was to compare the excitation current, no-load loss, load loss, regulation, and efficiency of the amorphous metal-core and silicon-steel transformers under loading conditions of 50 percent, 100 percent,

and 150 percent of rated load. To conduct the tests, the transformers were instrumented as prescribed in Section 8 of ANSI/IEEE C57.12.901980, and were operated at the selected fraction of rated load until the top oil temperature stabilized. Immediately following temperature stabilization, voltage, current, and power readings were taken to obtain the data to develop saturation curves and to calculate transformer regulation and efficiency at each loading condition for each transformer type. Regulation and efficiency were calculated using the procedures in Section 14 of ANSI/IEEE C57.12.90-1980. After completion of the saturation, regulation, and efficiency tests, the transformers were subjected to the commercial tests to determine whether any of the operating characteristics of the transformers changed as a result of the tests.

- Pass/Fail Criteria: The transformers had to pass the commercial tests after completion of the saturation, regulation, and efficiency tests. The core losses, exciting currents, and percent regulation of the amorphous metal-core transformer had to be less than those for the silicon-steel transformers. Also, the percent efficiency of the amorphous metal-core transformer had to be greater than that of the silicon-steel transformer. At rated input voltage, the no-load losses and load losses had to match the nameplate values. There had to be no change in the operating characteristics of the transformers as a result of the testing.

PHASE II TESTS

An autopsy conducted on two amorphous metal-core transformers during Phase I testing revealed that some amorphous metal particles had broken loose from the amorphous metal core. These particles were found at the bottom of the tank, on the inside of the bottom frame, and on the coils. It was believed that the presence of these particles in the oil would reduce the coil-to-coil insulation margin.

After all Phase I tests were completed, the transformers were returned to the General Electric Company Distribution Transformer plant, Hickory, North Carolina. At the suggestion of NCEL engineers, General Electric made a production-line change to correct the problem. A special device was made that rotated the amorphous metal-core and allowed the core to be sprayed with a special adhesive, which completely encapsulated the core.

The Phase II tests were conducted on five amorphous metal-core transformers. Four of the transformers had fully encapsulated cores. The remaining transformer was unmodified.

Several types of transformer tests were conducted in Phase II, including (in the following order) a cross-country shipping test, commercial transformer tests, an impedance voltage/load loss design test (prescribed in ANSI/IEEE C57.12.90-1980), an untanking and inspection of each transformer, a 3-foot drop test on three of the transformers, and a subsequent untanking and inspection of the three transformers. The identity, objective, and pass/fail criteria for the Phase II tests are described in the following paragraphs.

Cross-Country Shipping Test

- Objective: The objective of the cross-country shipping test was to demonstrate that the fully encapsulated amorphous metal-core transformers could withstand the shocks and vibrations encountered in cross-country shipment by commercial truck with no mechanical damage or change in electrical performance. For this test, five amorphous metal-core transformers were shipped by commercial truck from Hickory, North Carolina, to Port Hueneme, California, and back to North Carolina by commercial truck. Standard commercial packing and handling procedures were used.

- Pass/Fail Criteria: There had to be no visible damage from shipment. After shipment, the transformers had to pass the ANSI/IEEE Commercial tests, the ANSI/IEEE impedance voltage/load loss test, and the untanking and inspection test.

ANSI/IEEE Commercial Tests and Impedance Voltage/Load Loss Tests

- Objectives: The objectives for these tests are described in the corresponding Phase I test descriptions.

- Pass/Fail Criteria: The pass/fail criteria are described in the corresponding Phase I test descriptions.

- Commercial tests consist of the following:

  - Induced potential test per ANSI C57.12.90 - 1980 Sec 10.4.
  - No-load loss/exciting current per ANSI C57.12.90 - 1980 Sec 8.
  - Applied voltage tests per ANSI C57.12.90 - 1980 Sec 10.3.
  - Impulse per ANSI C57.12.90 - 1980 Sec 10.5.

- ANSI/IEEE impedance voltage/load loss test per ANSI C57.12.90 - 1980 Sec 9.

Initial Untanking and Inspection Test

- Objective: The objective of the initial untanking and inspection test was to determine the extent of mechanical damage, if any, to the transformer core or internal structure as a result of the cross-country shipping test.

- Pass/Fail Criteria: The criteria for passing the test was that there had to be no evidence of flaking of the amorphous metal within the transformer. In addition, there had to be no evidence of mechanical damage to the transformer internal structure that would impair the long-term, reliable operation of the transformer as a result of cross-country shipment and return (approximately 5,000 miles).

Drop Test

- Objective: The objective of the drop test was to simulate the shock that the transformer would receive if it were mishandled and inadvertently dropped from a height of 3 feet (from the bottom of the transformer tank) to a hard surface.

- Pass/Fail Criteria: The criteria for passing the test was that the transformer had to pass the subsequent untanking and inspection test, and the post-drop commercial tests.

Post-Drop Untanking and Inspection Test

- Objective: The objective of the post-drop untanking and inspection test was to determine the extent of mechanical damage, if any, to the transformer core or internal structure as a result of the drop test.

- Pass/Fail Criteria: The criteria for passing the test was that there had to be no evidence of flaking of the amorphous metal within the transformer. In addition, there had to be no evidence of mechanical damage to the transformer's internal structures that could impair the long-term, reliable operation of the transformer as a result of the 3-foot drop test.

TEST SEQUENCING

Proper test sequencing was an important aspect of the test program. In order to minimize potential damage to the transformers during testing, the resistance, polarity, phase relation, ratio, no-load loss and excitation current, impedance, load loss, and temperature rise tests were conducted before the dielectric tests (which test the transformer insulation levels) were performed. Also, in this transformer test program, the commercial tests were performed upon initial receipt of the transformers at the test facilities and after each group of tests in which stressful conditions were imposed.

Phase I Test Sequence

In Phase I, three 25-kVA amorphous metal-core transformers and two 25-kVA silicon-steel transformers were tested. The test sequence for each transformer is listed in Table 1.

Phase II Test Sequence

In Phase II, four 25-kVA amorphous metal-core transformers with fully encapsulated cores and one 25-kVA amorphous metal-core transformer without an encapsulated core were tested. The test sequence for the transformers is listed in Table 2.

RESULTS AND CONCLUSIONS

Phase I

The identity, objectives, and pass/fail criteria for the Phase I tests are described in the Phase I test descriptions. The sequence of testing for each transformer tested in Phase I is described in the section on test sequencing. The results and conclusions from the Phase I tests are provided in the following paragraphs.

Commercial Tests. These tests were performed: (1) to determine the electrical performance parameters of the transformers upon initial receipt before testing; (2) to demonstrate compliance with nameplate data or contractual agreements; and (3) to identify any significant changes in transformer performance characteristics after the transformers were subjected to individual stressful tests.

- Commercial Test Results: The results of the commercial tests are tabulated in Appendix A. All of the transformers passed the commercial tests because they met the test criteria specified for the applicable tests. For the amorphous metal-core transformers, the largest average change in no-load loss, load loss, efficiency, and regulation between the initial tests and the tests that imposed stressful conditions was 2.4 percent. The maximum change in any of these parameters was a 7.0 percent increase in no-load loss for amorphous metal-core transformer serial number P217060-YZA after the 170 percent temperature rise test.

- Commercial Test Conclusions: The conclusions from the results of the commercial tests were that the transformers demonstrated compliance with the nameplate data upon initial receipt, and there were no significant changes in transformer electrical characteristics after being subjected to tests that caused significant stresses.

Temperature Rise Tests. These tests were performed to determine the maximum temperature rise (above the ambient temperature) of the windings and the insulating fluid in the transformer when the transformer was operated at loads equal to, and greater than, the nameplate kVA rating. The amorphous metal-core transformers were operated at 100 percent and at 170 percent of nameplate load. The silicon-steel transformers were operated at 100 percent and 150 percent of nameplate load.

- Temperature Rise Test Results: The detailed results of the temperature rise tests are shown in Appendix B. The summarized results are listed in Table 3 and illustrated in Figure 1.

- Temperature Rise Test Conclusions: The conclusions to be drawn from the results of the temperature rise tests are as follows:

  - At 100 percent of rated load, both the amorphous metal-core and the silicon-steel transformers passed the temperature rise test. Both of the transformer types had temperature rises of less than the ANSI/NEMA requirement of 65 °C temperature rise above ambient.

  - At 100 percent of rated load, the temperature rise in the amorphous metal-core transformer oil, low-voltage windings, and high-voltage windings was significantly less than the corresponding temperature rises in the silicon-steel transformers.

  - The temperature rises in the amorphous metal-core transformers at 170 percent of rated load were roughly comparable to the temperature rises in the silicon-steel transformers at 150 percent of rated load.

The significance of the lower temperature rises in the amorphous metal-core transformers is that, other factors being equal, amorphous metal-core transformers should have longer reliable operating lives compared to silicon-steel transformers.

Audible Sound Level Test. The audible sound level test was conducted to determine the audible sound emitted from the transformer when operated at rated voltage and frequency and no-load. Sound level measurements are significant because excessive sounds from transformers can be an annoyance in residential or other populated areas. Also, excessive sound levels may indicate apparent problems in the transformer core, such as loose or fractured core laminations.

- Audible Sound Level Test Results: The audible sound level tests were conducted on amorphous metal-core transformer serial number P217059-YZA at 100 percent and 110 percent of rated voltage, after the transformer had been subjected to short-circuit testing. This worst-case condition was chosen to give an indication of any possible loosening or fracturing of core laminations as a result of the short-circuit test. The detailed test data are shown in Appendix B. The summarized audible sound level test data are listed below, and illustrated in Figure 2:

  Sound Level at 100% of Rated Voltage . . . . 32.4 dB(A)

  Sound Level at 110% of Rated Voltage . . . . 37.3 dB(A)

The ANSI/NEMA sound level limit at 100 percent of rated voltage is 48 dB(A). There is no ANSI/NEMA sound level limit at 110 percent of rated voltage.

- Audible Sound Level Test Conclusions: The conclusions from the test results were that the tested amorphous metal-core transformer operated at a sound level that was substantially lower than the ANSI/NEMA limit. The low sound level indicated that no core damage was incurred as a result of the previously conducted short-circuit test.

Radio Influence Voltage Test. The objective of the RIV test was to determine the amount of RIV produced by the corona (local overstress) in transformer insulation. RIV, as the name implies, may cause interference to radio communications. Excessive corona also may be an indication of insulation breakdown.

- RIV Test Results: The test produced no radio influence voltage at 100 percent and 110 percent of rated voltage.

- RIV Test Conclusion: The conclusion from the test results was that operation of the tested amorphous metal-core transformer at 100 percent of rated voltage or 110 percent of rated voltage would not interfere with radio transmission or reception.

Short-Circuit Test. The short-circuit test was conducted to demonstrate the ability of the transformer to withstand the stresses resulting from a short circuit applied on the transformer's primary or secondary terminals. The test may be conducted by closing a breaker at the faulted terminal, which would apply short circuit to a previously energized transformer, or by closing a breaker at the source terminal, which would apply energy to a previously short-circuited transformer.

- Short-Circuit Test Results: The detailed test results are shown in Appendix B. The summarized short-circuit test results are listed below and illustrated in Figure 3 for amorphous metal-core transformer serial number P217059-YZA when subjected to a short-circuit current of 40 times the rated current.

	Impedance Change	Exciting Current Change
As observed in before/after commercial tests	5.3%	1.0%
As allowed per ANSI/IEEE C57.12.90-1980	11.1%	25.0%

Measurements were also made of the first and sixth peak of the magnetizing in-rush current. These values were 28.8 and 12.8 times the normal magnetizing current. The transformer passed the commercial tests both before and after the short-circuit test. No damage attributable to the short-circuit test was found in a post-test autopsy.

- Short-Circuit Test Conclusion: The conclusion from the short-circuit test results was that the amorphous metal-core transformer can be expected to withstand short-circuit current of at least 40 times the rated current, without damage or significant change in electrical performance parameters.

Full-Wave and Chopped-Wave Impulse Voltage Tests. These tests were conducted to determine the ability of the transformer to withstand lightning surges. The test descriptions and pass/fail criteria are contained in the Phase I test descriptions. The chopped wave stressed insulation between turns near the line end. The full wave stressed insulation between the middle of the winding and ground. Oscillograms were obtained for applied voltage versus time and for neutral current versus time.

- Full-Wave and Chopped-Wave Impulse Voltage Test Results: The detailed test results are contained in Appendix B. The test sequence included the following tests: reduced full-wave test, chopped-wave test, 400-Hz induced potential test, front of wave impulse test (voltage wave is chopped before it crests), 400-Hz induced potential test, full-wave test, 400-Hz induced potential test, and HLIC and LHIC applied voltage tests. In order to provide additional assurance that the amorphous metal-core transformers could withstand lightning surges, the tests were performed on an energized transformer, and additional stress tests were added to the test sequence.

As stated in the Phase I test descriptions, agreement in voltage and current wave shape between the initial full-wave reduced voltage application and the final 100 percent full-wave application indicates that the transformer has passed without damage. Any unexplainable difference in wave shape indicates a failure in either the windings, the major or minor insulation, or the bushings.

As described in Paragraph 7 of Appendix B, two anomalies arose in the full-wave impulse tests. To determine if the anomalies indicated a failure in the insulation, the transformer was subjected to an induced voltage test at 400-Hz and the HLIC and LHIC applied voltage tests. The transformer passed these auxiliary tests. Therefore, the transformer was considered to have passed the full-wave and chopped-wave impulse voltage tests.

- Full-Wave and Chopped-Wave Impulse Voltage Test Conclusions: From the test results, it was concluded that the tested amorphous metal-core transformer was able to withstand simulated lightning surges, even when it was energized. It is noteworthy that these tests were more severe than the unenergized tests prescribed in ANSI/IEEE C57.12.90-1980.

Infrared Scanning Test (Transformer Energized). This test was conducted to obtain, by means of an infrared-sensitive detector, a visual indication of the amount of energy required to magnetize the transformer core. The infrared scans of an energized amorphous metal-core transformer and a silicon-steel transformer were compared.

- Infrared Scanning Test Results (Transformer Energized): Photographs of the infrared scan of the amorphous metal-core transformer and the silicon-steel transformer are contained in Appendix C. It can be seen that the intensity of radiation from the amorphous metal-core transformer is less than the intensity of radiation from the silicon-steel transformer. Also, there are no visible hot spots in the infrared scan of either transformer.

- Infrared Scanning Test Conclusions (Transformer Energized): The test results confirm the results of the commercial tests, which indicate that the core losses in the amorphous metal-core transformer are less than the core losses in the silicon-steel transformer.

Cold-Load Pickup Test. This test was conducted to determine whether heavy loading of a cold transformer had any injurious effects, such as thermal instability, on the transformer. The conditions that the test was designed to simulate are described in the Phase I test descriptions. For this test, the transformer was placed in a cold chamber until the oil temperature reached -34 °C. Then the transformer was energized at 200 percent load for 2 hours. This was followed by 6 hours of operation at 100 percent load. Watt loss was measured throughout the test.

- Cold-Load Pickup Test Results: The detailed test results are contained in Appendix B. In summary, within a relatively short time, the losses stabilized at both loading conditions and remained fairly constant throughout the remainder of each test iteration. Subsequently, the transformer passed the commercial test.

- Cold-Load Pickup Test Conclusions: From the results of the tests, it was concluded that the tested amorphous metal-core transformer can satisfactorily withstand being subjected to a 200 percent cold load when the transformer oil temperature is -34 °C. Further, the transformer can operate satisfactorily for an extended period at 100-percent load after the 200 percent load period. This realistic test demonstrated that the transformer design is sufficient to adequately circulate the transformer oil during a cold load. No damage to the transformer insulation is likely to occur as a result of hot spots caused by poor transformer circulation.

Saturation, Efficiency, and Regulation Tests. These tests were conducted to compare the excitation current, no-load loss, load loss, regulation, and efficiency of the amorphous metal-core and silicon-steel transformers under loading conditions of 50 percent, 100 percent, and 150 percent of rated load. The tests were run as described in the Phase I test descriptions.

- Saturation, Efficiency, and Regulation Test Results:

  - Saturation: The excitation current in the amorphous metal-core transformer was significantly lower (0.25 to 0.5) than the excitation current in the silicon-steel transformer for all loading conditions and all values of secondary voltage. The test data are listed in tabular form in Appendix D, and illustrated in Figures 4 through 7.

  - No-Load Losses: The no-load losses of the amorphous metal-core transformer were significantly lower than the no-load losses of the silicon-steel transformer for all loading conditions and all values of secondary voltage. At 100 percent of rated flux voltage, the no-load loss of the amorphous metal-core transformer was 27 percent of the no-load loss for the silicon-steel transformer. The actual values closely approximated the nameplate values for both transformers. The test data are provided in tabular form in Appendix D and in Figures 8 through 11.

  - Regulation: Both the measured and calculated percent regulation of the amorphous metal-core transformer was better (lower) than the measured or calculated percent regulation of the silicon-steel transformer at 50 percent, 100 percent, and 150 percent load for both 0.8 and 1.0 power factors. The test data are provided in tabular form in Appendix B for all loading conditions, and illustrated in Figure 12 for 100 percent loading.

  - Efficiency: Both the measured and calculated efficiency of the amorphous metal-core transformer was better (higher) than the measured or calculated efficiency of the silicon-steel transformer at 50 percent, 100 percent, and 150 percent load for both 0.8 and 1.0 power factors. The test data are provided in tabular form in Appendix B and illustrated in Figure 13 for 100 percent loading.

The electrical parameters of the amorphous metal-core transformer showed very little variation from previous values after the saturation, efficiency, and regulation tests were completed. See Appendix A for the detailed results of the commercial tests conducted before and after the saturation, efficiency, and regulation tests.

- Saturation, Efficiency, and Regulation Test Conclusions: The amorphous metal-core transformer performed better in all tests than the silicon-steel transformer. There were no significant changes in the electrical parameters of the amorphous metal-core transformer as a result of the testing.

Safe Transit (Shake and Drop) Tests. These tests were conducted to demonstrate that the transformer could withstand the shocks and vibrations encountered during a simulated cross-country shipment, with no significant

mechanical damage and no significant change in electrical performance characteristics. Two tests were run: (1) a 4-hour test on the safe transit machine at 160 rpm to simulate two cross-country shipments by truck, and (2) a 4-foot drop of the transformer onto a hard surface (to simulate inadvertent mishandling during transit). After the shake and drop tests, the transformer was subjected to the commercial tests to detect any changes in electrical performance and to an autopsy where the transformer core was removed from the tank and inspected for damage. The pass/fail criteria are described in the Phase I test descriptions.

- Safe Transit (Shake and Drop) Test Results: The transformer passed the shake and drop tests with no significant external damage. When the shake and drop tests were completed, the amorphous metal-core transformer was subjected to the commercial tests. The transformer passed the tests with a 3 percent drop in no-load loss, which was substantially less than the allowed 10 percent drop. There were no significant changes in the other electrical performance parameters of the transformer (see Appendix A).

- Safe Transit (Shake and Drop) Test Conclusions: The preliminary conclusion from the shake and drop tests was that the transformer passed the tests. See the autopsy test results in the following paragraph for further discussion of the test results.

Post-Shake and Drop Test Autopsy. The post-drop untanking and inspection was done to determine the extent of mechanical damage, if any, to the transformer core or internal structures as a result of the drop test.

- Post-Shake and Drop Test Autopsy Results: When the transformer was untanked, minor mechanical damage to the tank bottom (a bowed core/coil and cracked core/coil pressure plates) was found. In addition, amorphous metal-core particles were found on the bottom of the tank, on the inside of the bottom frame, and on the coils. See Figure 1 in Section 8 of Appendix B.

- Post-Shake and Drop Test Autopsy Conclusions: The criteria for passing the test were that there had to be no evidence of the amorphous metal flaking in the transformer core and there had to be no evidence of mechanical damage to the transformer internal structures that could impair the long-term, reliable operation of the transformer as a result of the drop test. The mechanical damage to the exterior of the tank and to the internal core/coil support structures was not considered to be serious considering the severity of the test.

The presence of amorphous metal particles in the tank, on the coils, and in the tank oil was considered serious. The presence of these particles would reduce the coil-to-coil insulation margin of the transformer. Therefore, it was concluded that the transformer had not passed the post-test autopsy.

NOTE

After all Phase I tests were completed, the transformers were returned the General Electric Company Distribution Transformer Division plant, Hickory, North Carolina. At the suggestion of NCEL engineers, General Electric devised a production-line change to completely encapsulate the core and correct the problem.

Phase II

The identity, objectives, and pass/fail criteria for the Phase II tests are described in the Phase II test descriptions. The sequence of testing for each transformer tested in Phase II is set forth in the Phase II test sequence. The General Electric Company test data are contained in Appendix E. The results and conclusions from the Phase II tests are provided in the following paragraphs.

Cross-Country Test. The cross-country test was conducted to demonstrate that the amorphous metal-core transformers could withstand the shocks and vibrations encountered in cross-country shipment by commercial truck with no mechanical damage or change in electrical performance. For this test, five 25-kVA amorphous metal-core transformers were shipped by commercial truck from Hickory, North Carolina, to Port Hueneme, California, and back to North Carolina by commercial truck. Standard commercial packing and handling procedures were used.

- Cross-Country Test Results: From the results of the post-transport untanking of the transformers, there was no visible damage from the approximately 5,000-mile truck transport of the transformers. The results of the before and after commercial tests indicated no changes in electrical performance parameters that were outside the allowed variations. There was no indication of amorphous metal particle flaking in the four encapsulated transformers. Fifteen small amorphous metal particles were found in the bottom containment box of the nonencapsulated transformer.

- Cross-Country Test Conclusions: All five transformers passed the cross-country test, and the subsequent commercial and untanking and autopsy tests (see Appendix A for the commercial test results). It was further concluded that the amorphous metal-core transformers could withstand the typical shocks and vibrations encountered in cross-country truck shipment without physical damage or significant change in electrical parameters.

3-Foot Drop Test. The 3-foot drop test was conducted on three of the transformers to simulate the shock that the transformer would receive if it was mishandled, and inadvertently dropped, from a height of 3 feet (from the bottom of the transformer tank) to a hard surface. The test procedure, test data, and test photographs are contained in Appendix E.

- 3-Foot Drop Test Results: The results of the drop test were as follows:

  - In all three transformers, the tank bottom had bulged and the bottom clamp had been bent, but none of the embossed areas of the containment tray were punctured.

  - The top and bottom clamp assemblies of all three units were very clean. There was no evidence of amorphous metal particles.

  - There were seven small amorphous metal particles in the bottom of the nonencapsulated transformer containment box.

  - There were four small amorphous metal particles inside the bottom containment box of one of the encapsulated transformers (serial number P265882-YOB).

  - There was one small amorphous metal particle inside the bottom containment box of the other encapsulated transformer (serial number P265885-YOB).

  - There were no amorphous metal particles in the oil or the inside of the transformer tank of all three transformers.

- 3-Foot Drop Test Conclusions: From the 3-foot drop test results, it was concluded that the encapsulated transformers passed the test. The significance of the test results is that the amorphous metal flaking problem experienced in the drop tests of Phase I has been solved.

DISCUSSION

NCEL successfully verified the reliability and performance of amorphous metal-core transformers over a 5-month test period. The amorphous metal-core transformers met or exceeded the ANSI/IEEE or NEMA standard for all tests conducted. The amorphous metal-core transformers performed better in all tests when compared to conventional silicon-steel transformers. In addition, NCEL verified that the no-load losses of the amorphous metal-core transformers were equal to or lower than the values claimed by the transformer manufacturer.

During Phase I testing, a problem was discovered with amorphous metal particles breaking loose from the transformer core. These particles were found in the bottom of the tank, on the inside of the bottom frame, and on the coils of the transformer. Consequently, the amorphous core transformers failed the safe transit tests. NCEL suggested a production-line change to General Electric, recommending complete encapsulation of the transformer core. This recommendation was implemented by the General Electric Company. Subsequent testing in Phase II demonstrated that the amorphous metal flaking problem had been resolved through complete encapsulation of the amorphous transformer core.

CONCLUSIONS

In every electrical performance test, the amorphous metal-core transformers met or exceeded the ANSI/IEEE or NEMA standard for the test.

The amorphous metal-core transformers also passed other more stress-inducing tests, such as the energized impulse voltage tests, the front of wave impulse test, the safe transit test, and the cold-load pickup test.

In every test where the electrical performance of amorphous metal-core and silicon-steel transformers was compared, the amorphous metal-core transformers performed better than the silicon-steel transformers.

The no-load losses of the amorphous metal-core transformers were equal to or lower than previous predictions made by the transformer manufacturer.

The amorphous metal flaking problem discovered in the Phase I tests appears to have been solved effectively by the production-line modification made at the suggestion of NCEL engineers.

Based on the test results, it is reasonable to expect that the amorphous metal-core transformers will operate with equal or better reliability than the silicon-steel transformers over the nominal lifetime of a transformer.

RECOMMENDATIONS

Based on the results of the tests, the following recommendations are made:

1. Up to 500 kVA amorphous metal-core transformers should be procured as replacements based upon life-cycle cost analysis for up to 500 kVA polychlorinated biphenyl (PCB) contaminated transformers and for replacement of other transformers through 500 kVA requiring replacement due to age, loading, or maintenance.

2. The development and commercial availability of larger kVA-capacity amorphous metal-core transformers should be closely followed.

3. As larger kVA-capacity transformers become commercially available, they should be procured as replacements for similar size PCB-contaminated transformers, and for replacement of other similar-size transformers requiring replacement due to age, loading, or maintenance.

4. All amorphous transformer cores should be specified as fully encapsulated in order to eliminate metallic flaking.

Executive Summary of Test Results

Phase I Testing	25 kVA/75 kV BIL Amorphous Metal Test Status	25 kVA/75 kV BIL Silicon Steel Test Status	Test Object Pass/Fail Criteria Description	Test Standard Used
ANSI "Routine" Testing				
Ratio	P	P	Page 2	ANSI C57.12.90 - 1980 Sec. 7
Polarity	P	P	Page 2	ANSI C57.12.90 - 1980 Sec. 6
Applied Voltage HLIC Test	P	P	Page 3	ANSI C57.12.90 - 1980 Sec. 10.3
Applied Voltage LHIC Test	P	P	Page 3	ANSI C57.12.90 - 1980 Sec. 10.3
Induced Potential Test	P	P	Page 3	ANSI C57.12.90 - 1980 Sec. 10.4
No-Load Loss/Exciting Current	C	C	Page 3	ANSI C57.12.90 - 1980 Sec. 8
ANSI "Design" Tests				
Full-Wave Impulse	P	P	Page 4	ANSI C57.12.90 - 1980 Sec. 10.5
Chopped-Wave Impulse	*	X	Page 4	ANSI C57.12.90 - 1980 Sec. 10.5
Winding Resistance	C	C	Page 4	ANSI C57.12.90 - 1980 Sec. 9
Impedance/Load Loss	C	C	Page 5	ANSI C57.12.90 - 1980 Sec. 9
Temperature Rise	P	P	Page 5	ANSI C57.12.90 - 1980 Sec. 11
Sound Level	P	X	Page 5	ANSI C57.12.90 - 1980 Sec. 13 ANSI/IEEE Std. 141 - 1986 NEMA TR1 - 1980
ANSI "Other" Tests				
Radio Influence Voltage (RIV)	P	X	Page 6	NEMA TR1-1980 Revision 2 Sec. 0.03 (Limits) NEMA 7.01 (Test Code) NEMA 107 - 1964 Reaffirmed 1981 Test Methods
Short Circuit	P	X	Page 6	ANSI C57.12.90 - 1980 Sec. 12

Executive Summary of Test Results (Continued)

Phase I Testing	25 kVA/75 kV BIL Amorphous Metal Test Status	25 kVA/75 kV BIL Silicon Steel Test Status	Test Object Pass/Fail Criteria Description	Test Standard Used
**Additional Tests				
Front of Wave Impluse	*	X	Page 4	
Full-Wave Impulse-Energized	P	X	Page 4	
Chopped-Wave Impulse-Energized	P	X	Page 4	
Front of Wave Impulse-Energized	P	X	Page 4	
Safe Transit Test (Shake & Drop)	P	X	Page 6	
Infrared Scanning-Energized	C	C	Page 7	
Cold-Load Pickup	P	X	Page 7	
Saturation Curves	C	C	Page 7	
Regulation & Efficiency	C	C	Page 7	

P = Passed Test

F = Failed Test

C = Testing Completed - No Pass/Fail Criteria Available

* = See Same Test With Unit Energized

Q = Qualified Pass

X = This Test Not Part of Test Program for Silicon Steel Units

** = These Tests are not defined or required by ANSI and/or NEMA Standards.
These tests were defined by NCEL

Executive Summary of Test Results

Phase II Testing	25 kVA 75 kV BIL/kVA Amorphous Metal Test Status	Test Objective Pass Fail Criteria Description	Standards Used
Cross-Country Shipping Test*	P	Page 9	ANSI C57.12.90 - 1980 Section 4, 8, 9, 10.3, 10.5
Drop Test*	P	Page 10	ANSI C57.12.90 - 1980 Sections 4, 8, 9, 10.3 10.5
Post-Drop Test*	P	Page 10	

P = Passed Test
F = Failed Test
C = Testing Completed - No Pass/Fail Criteria Available
* = These Tests are not defined or required by ANSI and/or NEMA Sandards.
These Tests were defined by NCEL

FUTURE WORK

Amorphous metal-core transformers are an emerging new technology that will meet the typical wide swings in Navy transformer load requirements of no-load to full load. Currently, 25-kVA through 75-kVA production-grade amorphous metal-core transformers are commercially available. Pilot-line 75-kVA through 500-kVA amorphous metal-core transformers are also available. Industry projections indicate that amorphous metal-core transformers will be price comparable in the 1990s and will eventually dominate the transformer market.

NCEL will focus efforts on low core loss transformer technology due to the potential of large Navywide energy savings. Eight three-phase, pad-mounted, amorphous metal-core transformers (three 75-kVA units and five 150-kVA units) are currently being field tested by NCEL at Pearl Harbor, Hawaii. NCEL plans to field test a 300-kVA unit at the Pacific Missile Test Center, Point Mugu, California.

ACKNOWLEDGMENTS

The authors wish to acknowledge Mr. Gregg V. Jones of the Westinghouse Electric Corporation and Mr. Albert C. Lee of General Electric for their assistance in analyzing and interpreting the test data.

Table 1. Phase I Transformer Test Sequences

Amorphous Metal-Core Transformer Test Sequence		
Serial Number P217059-YZA	Serial Number P217060-YZA	Serial Number P217061-YZA
Commercial Tests[a] Short-Circuit Test Sound Level Test RIV Test Commercial Tests[a] 4-hour Shake Test Commercial Tests[a] 4-Foot Drop Test Commercial Tests[a] Autopsy	RIV Test Commercial Tests[a] 100% Temperature Rise 170% Temperature Rise Commercial Tests[a] Impulse Tests[b] (Energized) Infrared Scan	RIV Test Commercial Tests 100% Temperature Rise 170% Temperature Rise Commercial Tests[a] Cold-Load Pickup Test Commercial Tests[a] Regulation Tests Efficiency Tests Saturation Tests Commercial Tests[a]

Silicon-Steel Transformer Test Sequence	
Serial Number P239216-YOB	Serial Number P239217-YOB
Infrared Scan 100% Temperature Rise 150% Temperature Rise Commercial Tests[a] Regulation Tests Efficiency Tests Saturation Tests Commercial Tests[a]	100% Temperature Rise 150% Temperature Rise Commercial Tests[a]

[a]The commercial tests included the ratio test, full-wave impulse test, applied potential tests (HLIC and LHIC), induced potential (400-Hz) test, no-load/exciting current test, winding resistance test, and impedance voltage/load loss test.

[b]The impulse tests (with the transformer energized) were conducted in the following order: reduced full-wave test, chopped-wave test, 400-Hz front-of-wave test, 400-Hz full-wave test, and 400-Hz HLIC and LHIC tests.

Table 2. Phase II Transformer Test Sequences

Serial Number P217059-YZA[a]	Serial Number P217060-YZA[a]	Serial Number P217061-YZA[a]
Commercial Test Cross-Country Test Commercial Test Autopsy	Commercial Test Cross-Country Test Commercial Test Autopsy	Commercial Test Cross-Country Test Commercial Test Autopsy 3-Foot Drop Test Autopsy

Serial Number P265882-YOB[a]	Serial Number P265885-YOB[a]
Commercial Test Cross-Country Test Commercial Test Autopsy 3-Foot Drop Test Autopsy	Commercial Test Cross-Country Test Commercial Test Autopsy 3-Foot Drop Test Autopsy

[a]Amorphous metal-core transformer with encapsulated core.

Table 3. Summary of Temperature Rise Results

Serial Number	Core Material	Top Oil Temp Rise (°C)	HV Winding Temp Rise (°C)	LV Winding Temp Rise (°C)
Amorphous and Silicon Transformers at 100% of Rated Load				
P217060-YZA	Amorphous	39.1	48.9	47.5
P217061-YZA	Amorphous	39.4	51.7	50.4
P239216-YOB	Silicon	53.7	60.2	58.8
P239217-YOB	Silicon	52.1	59.6	60.8
Avg Silicon Temp Rise (°C)		52.90	59.90	59.80
Avg Amorphous Temp Rise (°C)		39.25	50.30	48.95
Temp Rise Difference (°C)		13.65	9.60	10.85
Amorphous at 170% Rated Load and Silicon at 150% Rated Load				
P217060-YZA	Amorphous	101.71	127.5	122.4
P217061-YZA	Amorphous	101.71	129.2	123.4
P239216-YOB	Silicon	102.1	120.6	112.5
P239217-YOB	Silicon	99.81	118.8	110.2
Avg Amorphous Temp Rise (°C)		101.70	128.35	122.90
Avg Silicon Temp Rise (°C)		100.95	119.70	111.35
Temp Rise Difference (°C)		0.75	8.65	11.55

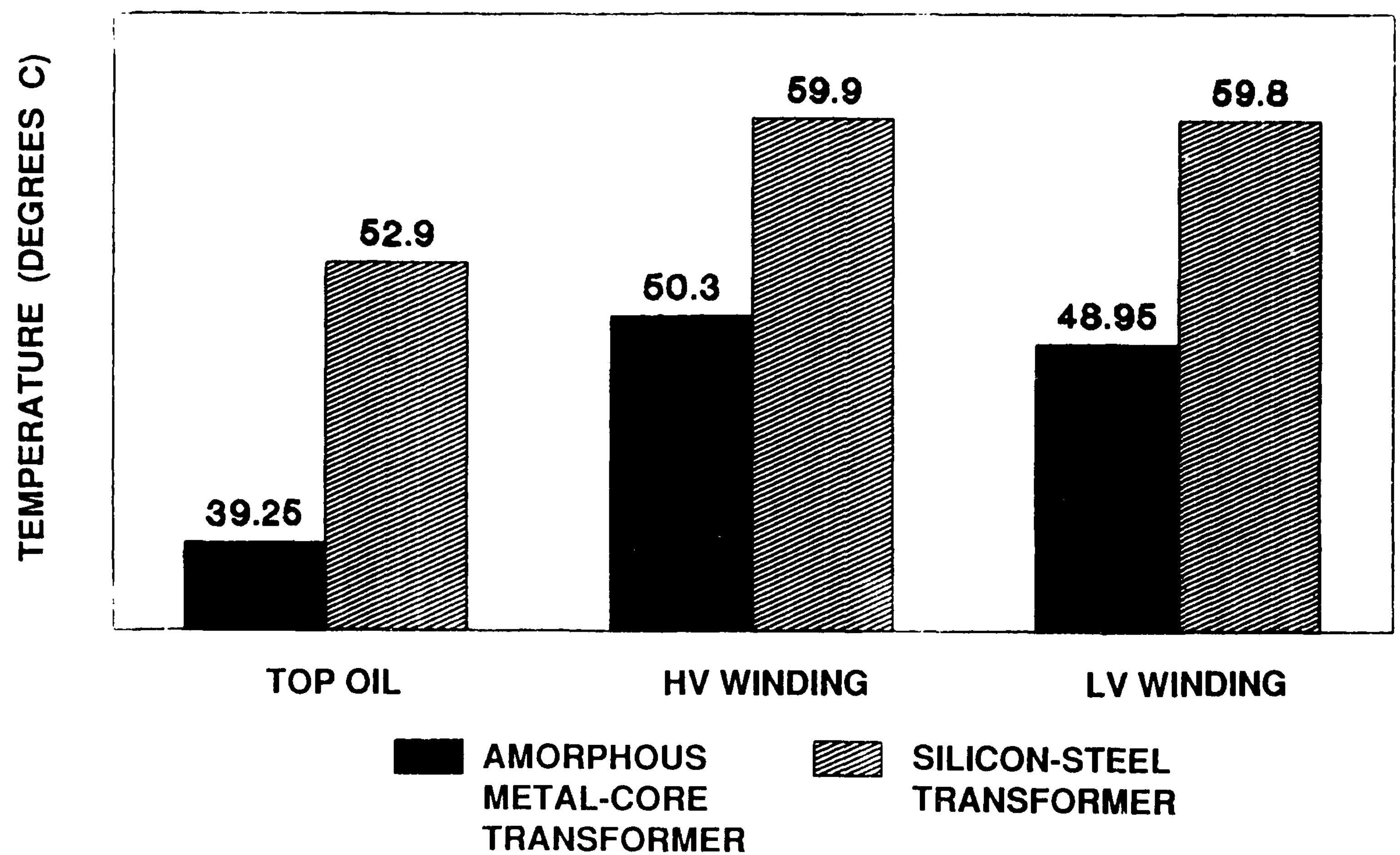

Figure 1. Temperature rise test at 100% load.

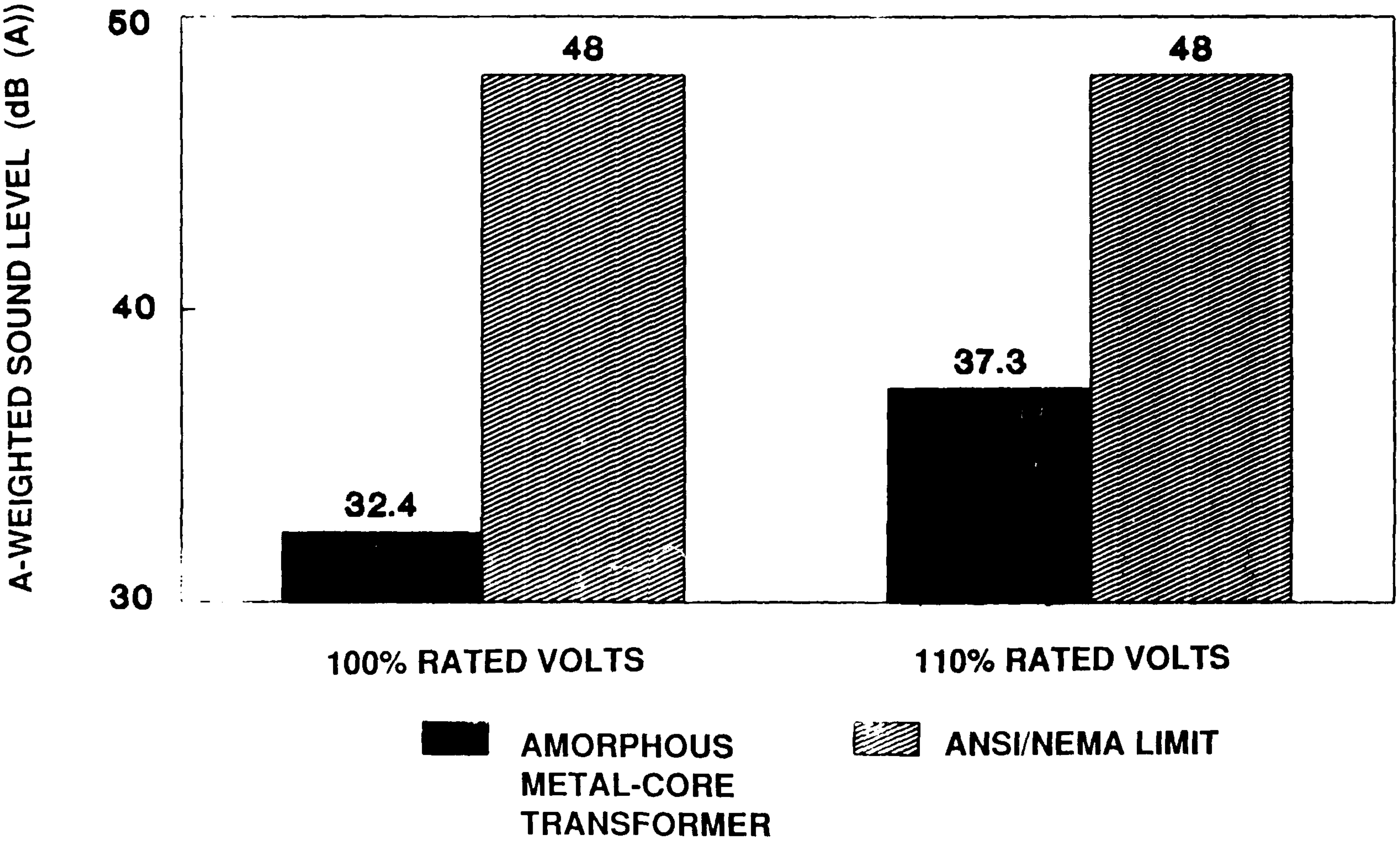

Figure 2. Audible sound level test.

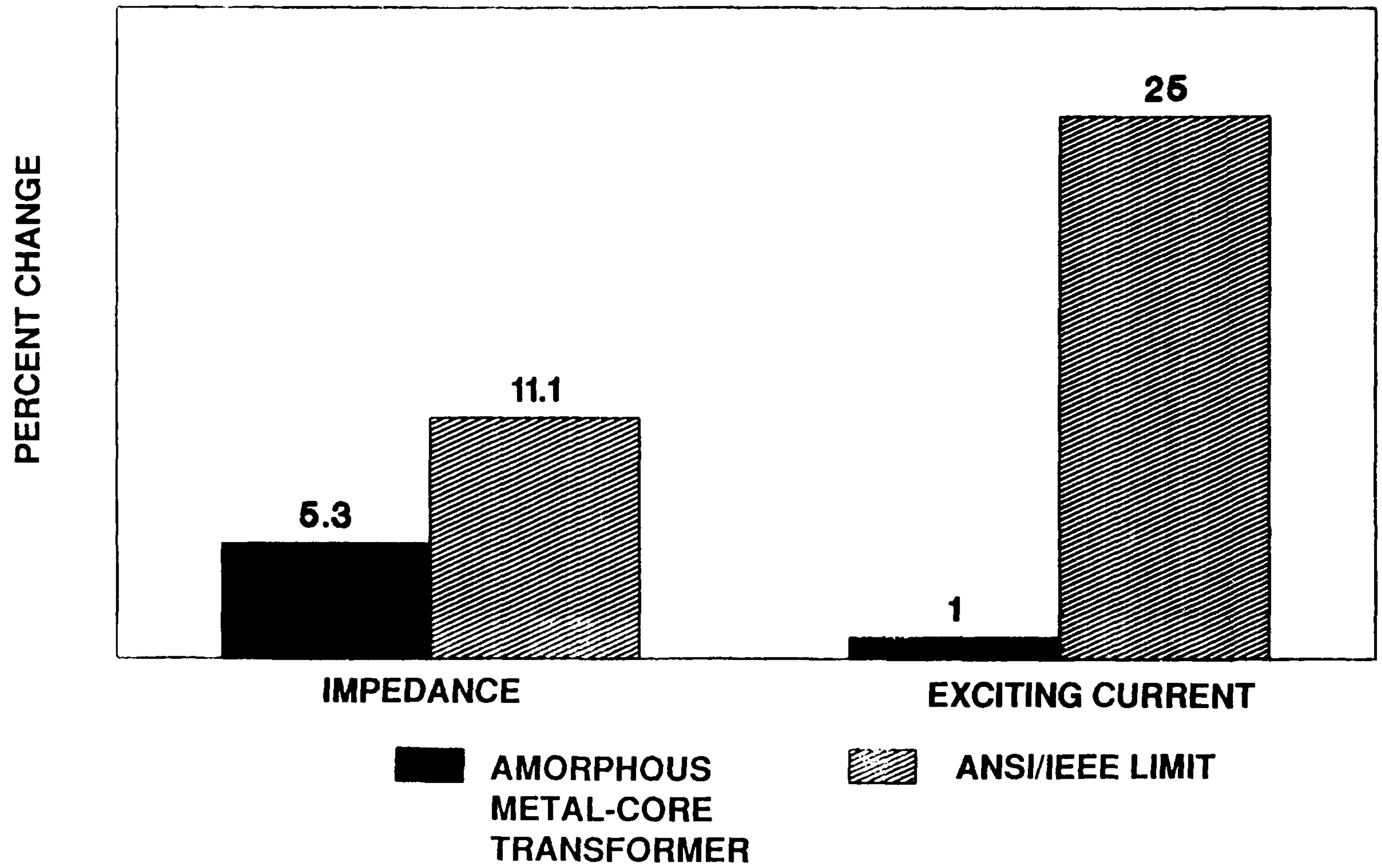

Figure 3. Short-circuit test.

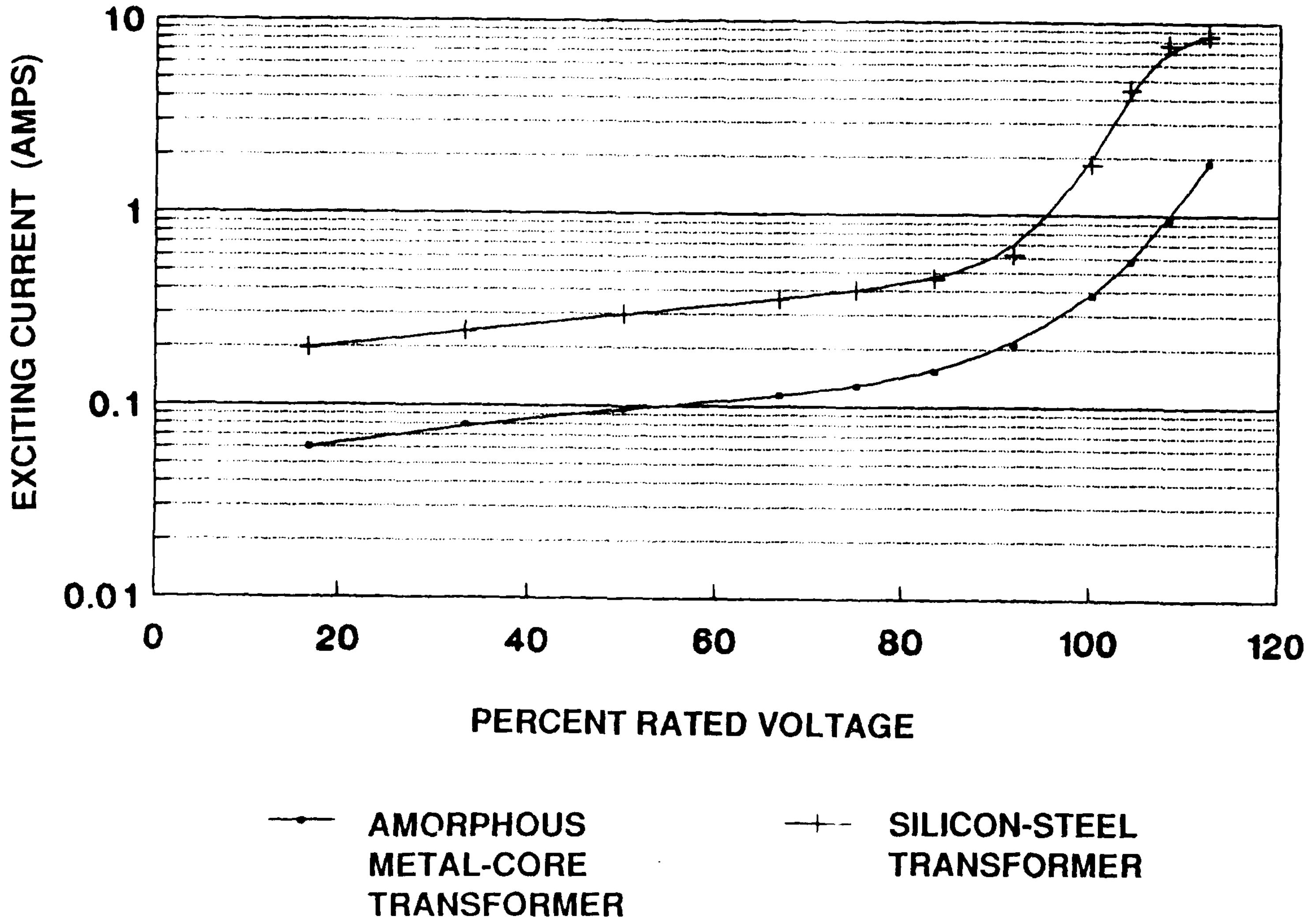

Figure 4. Exciting current versus % rated flux volts at no-load condition.

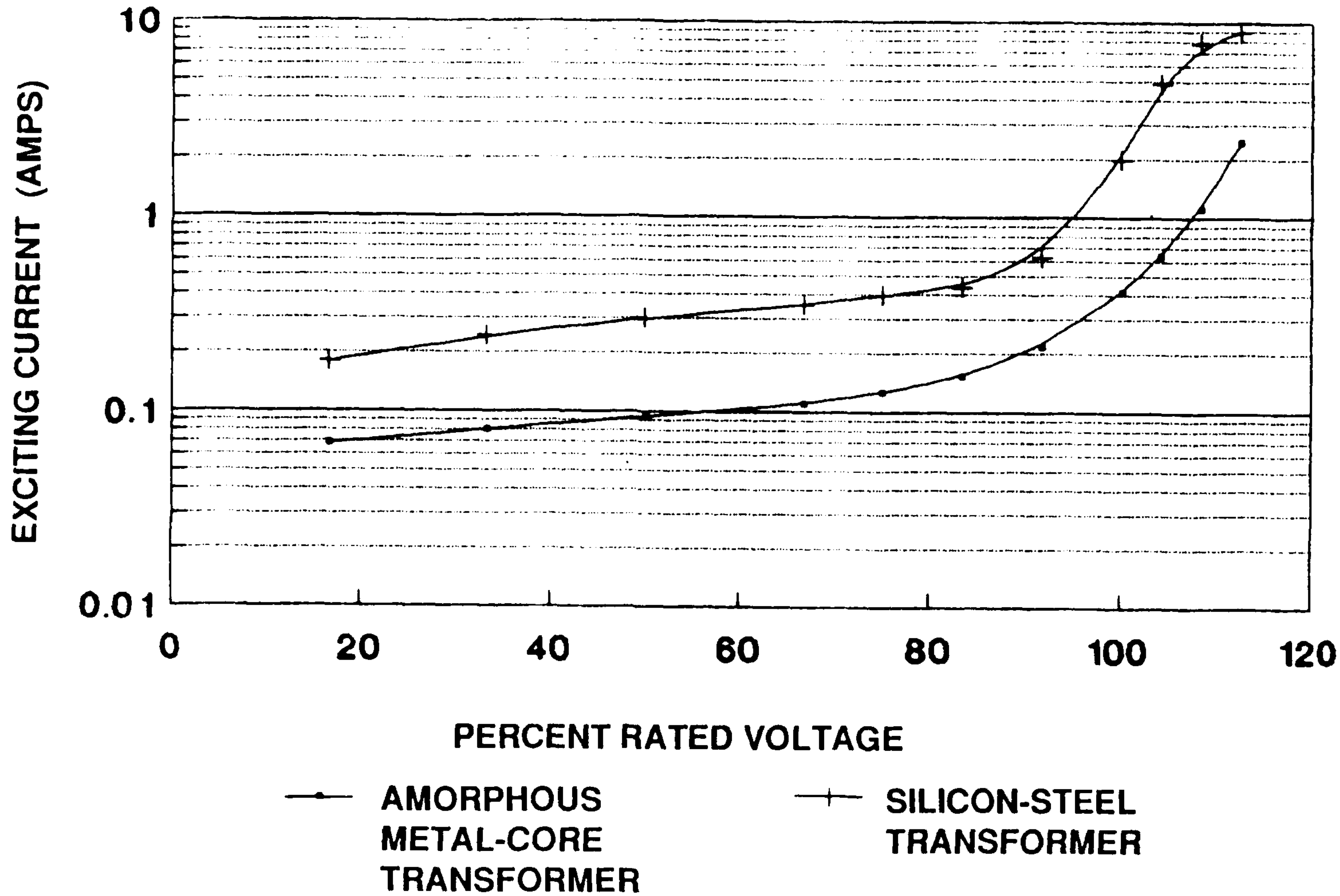

Figure 5. Exciting current versus % rated flux volts at 50% load condition.

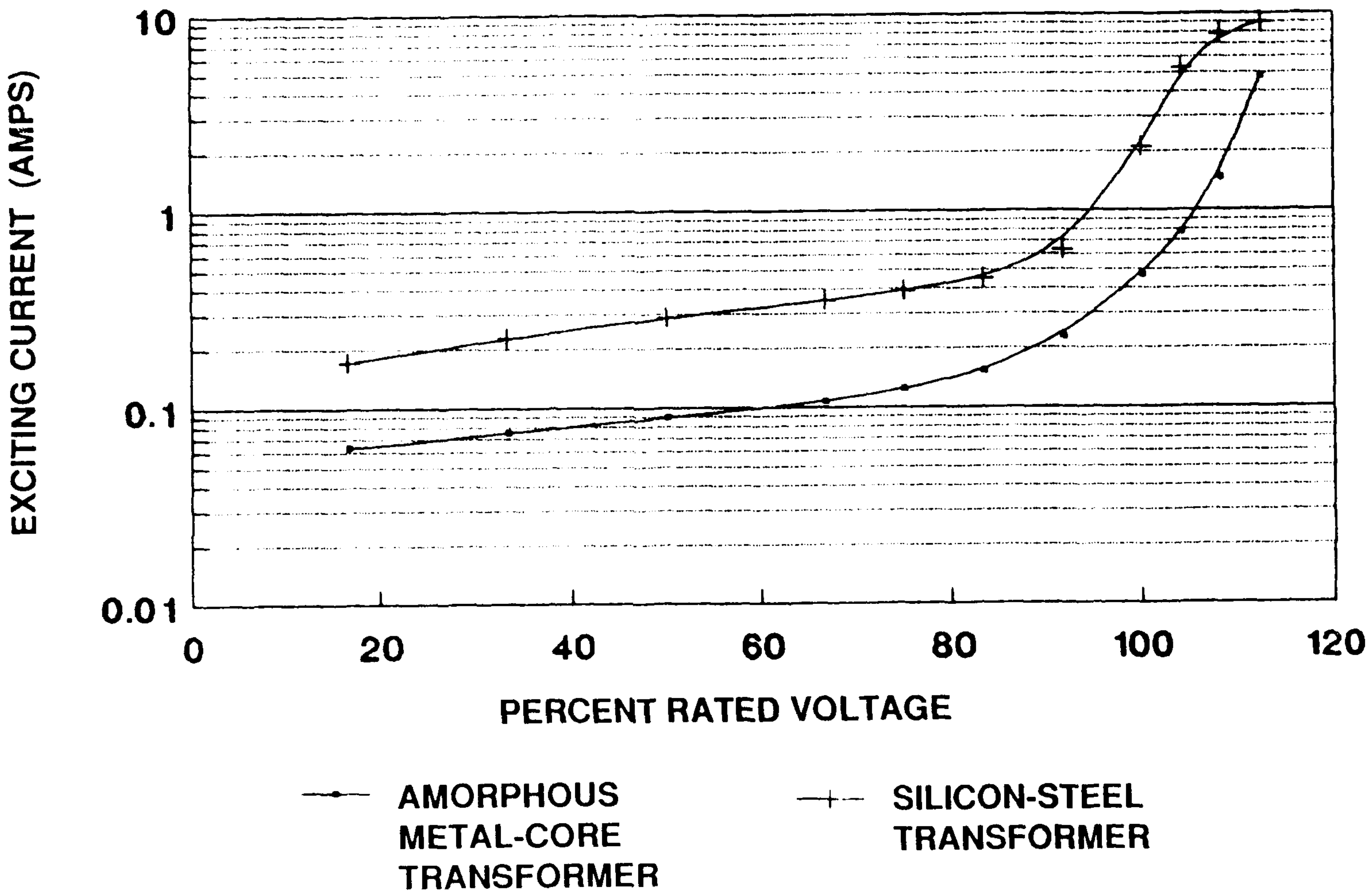

Figure 6. Exciting current versus rated flux volts at 100% load condition.

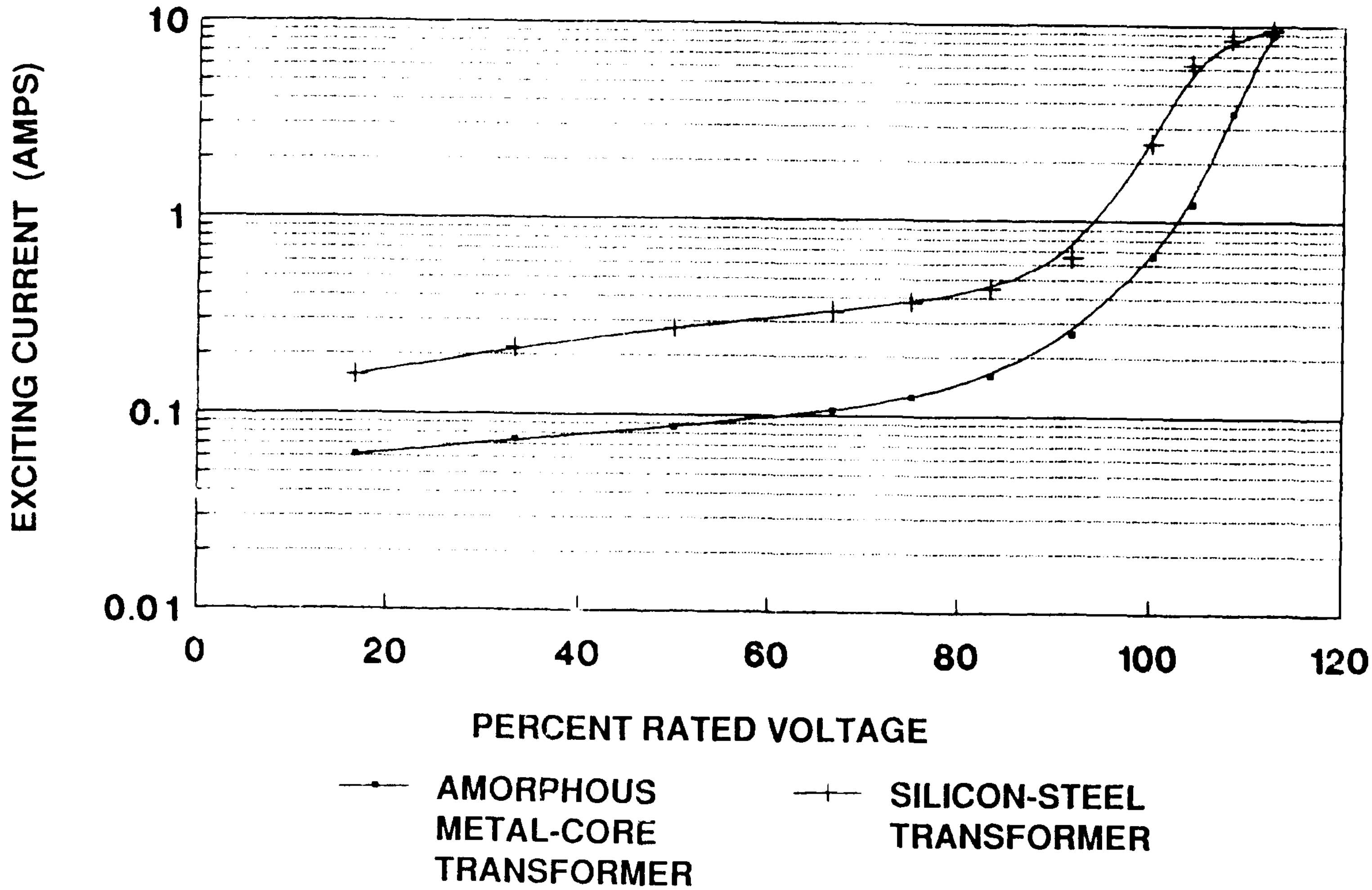

Figure 7. Exciting current versus rated flux volts at 150% load conditions.

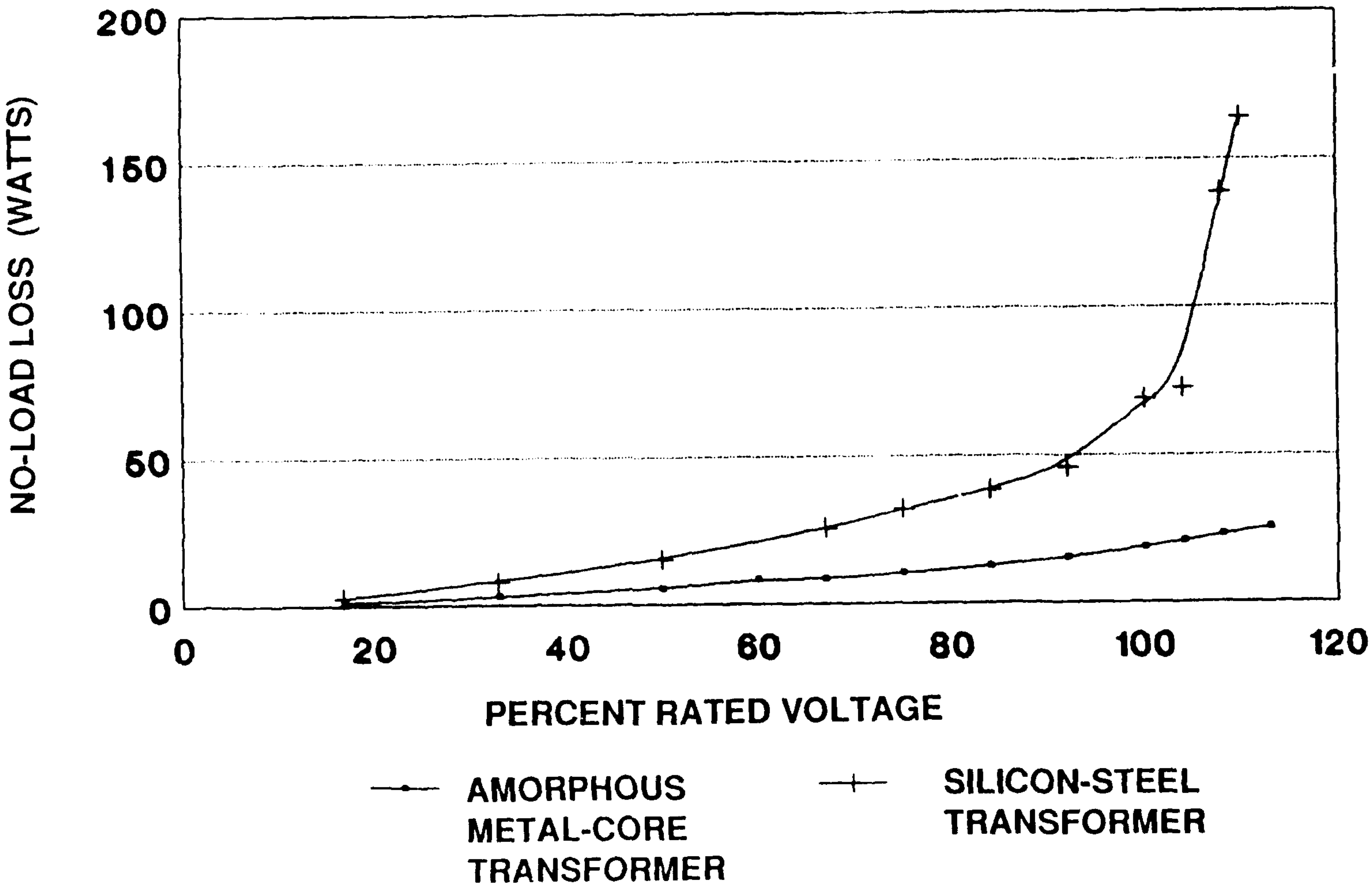

Figure 8. No load loss versus % rated flux voltage at no-load condition.

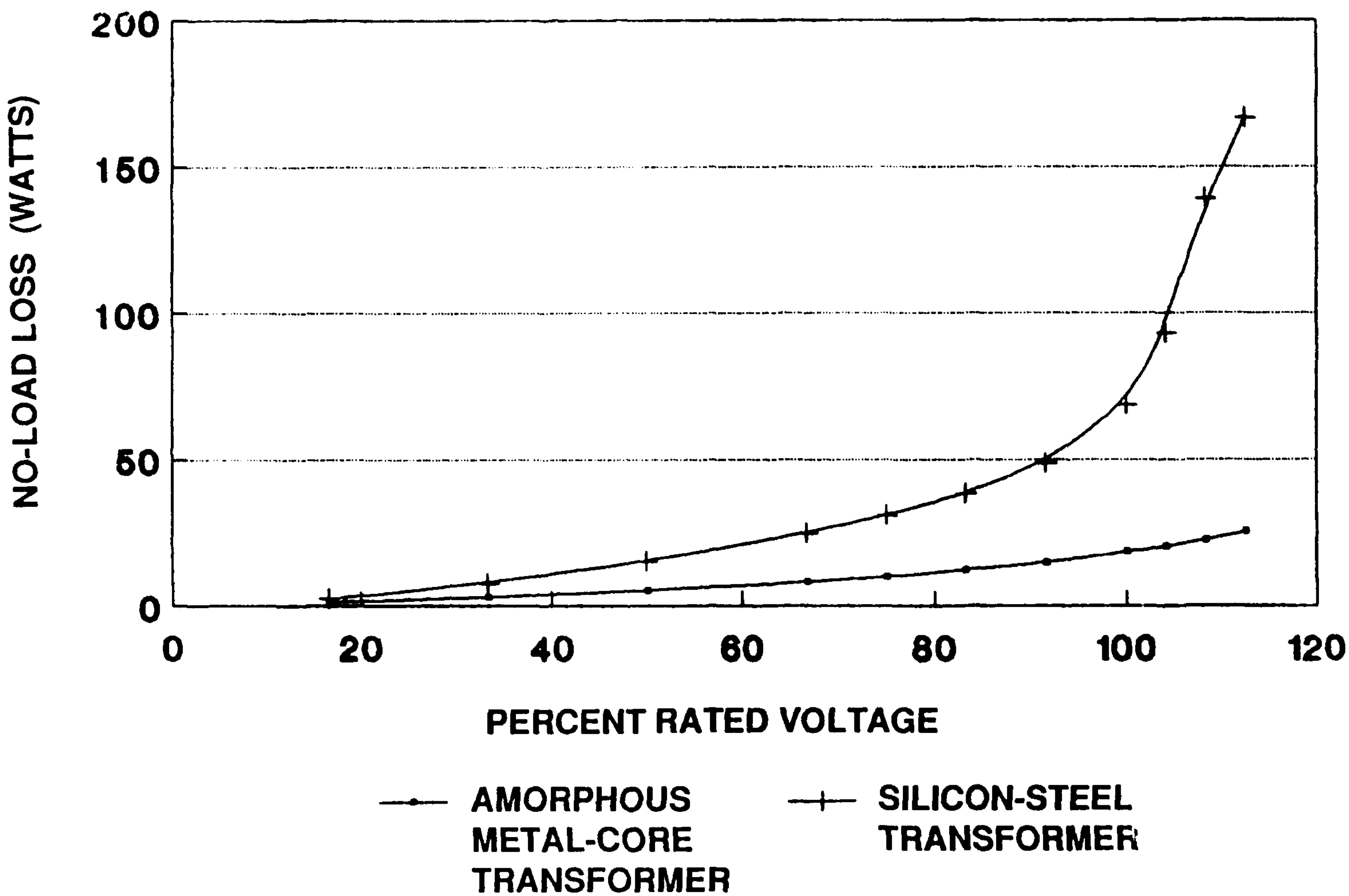

Figure 9. No-load loss versus % rated flux voltage at 50% load condition.

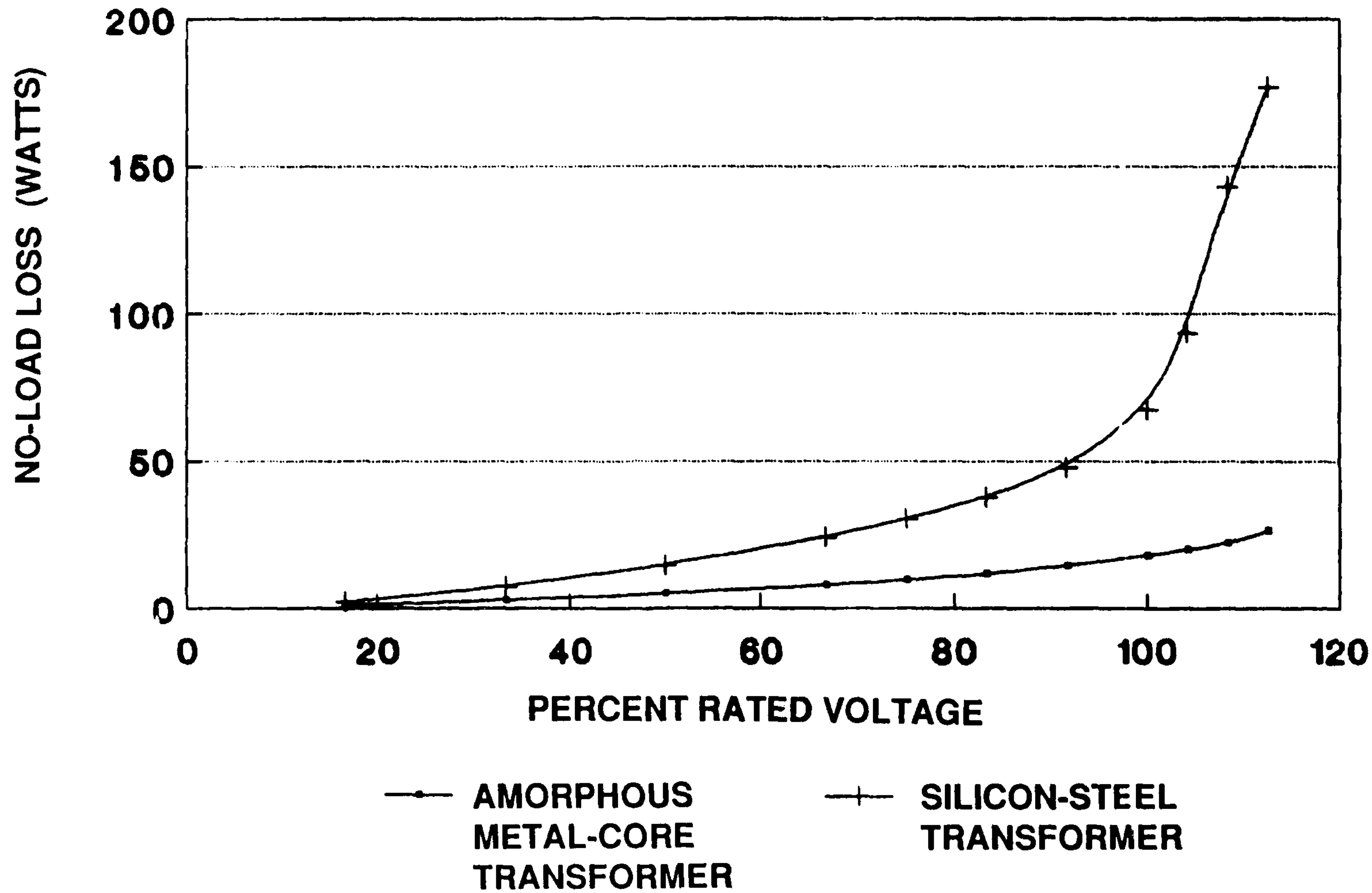

Figure 10. No-load loss versus % rated flux voltage at 100% load condition.

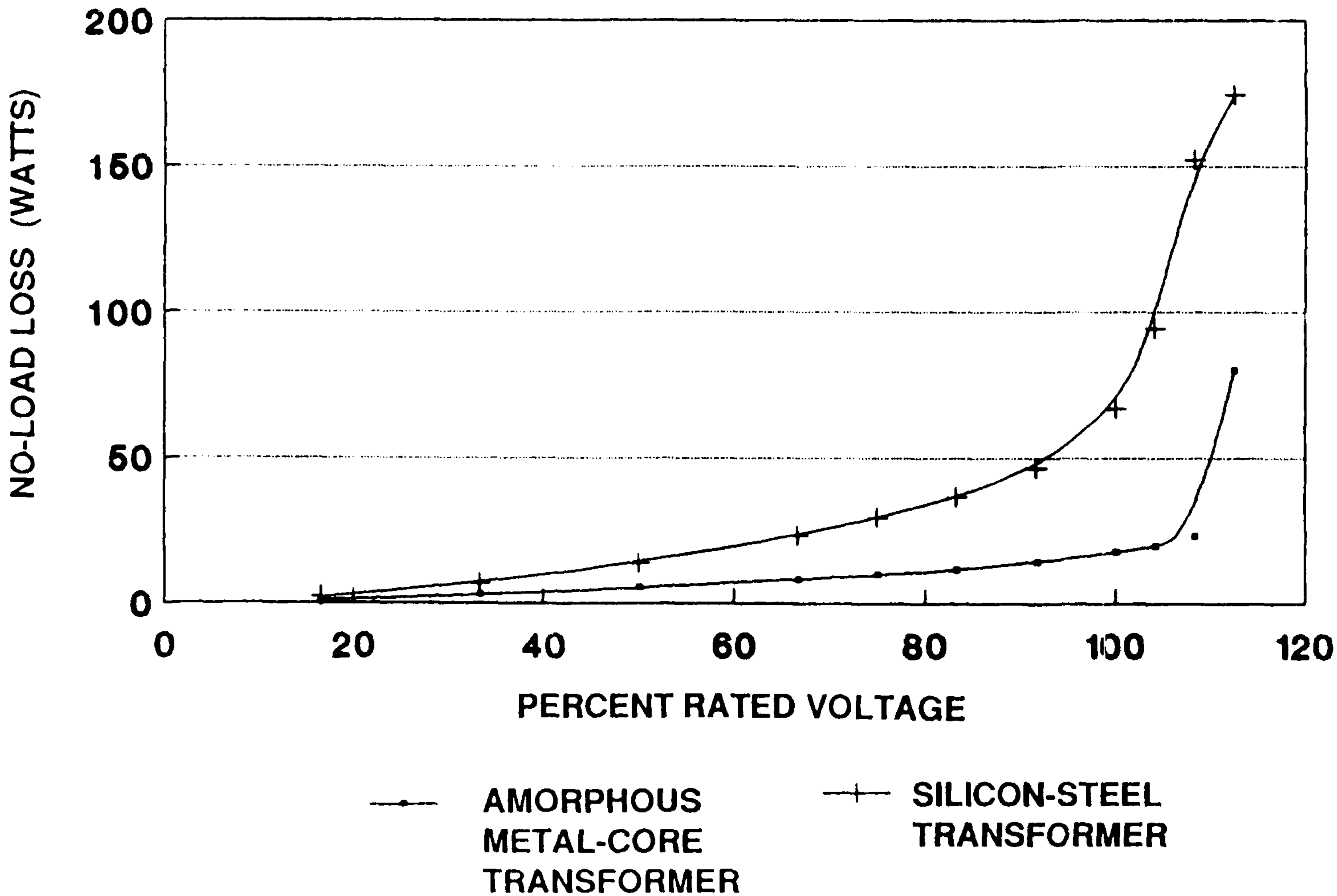

Figure 11. No-load loss versus % rated flux voltage at 150% load condition.

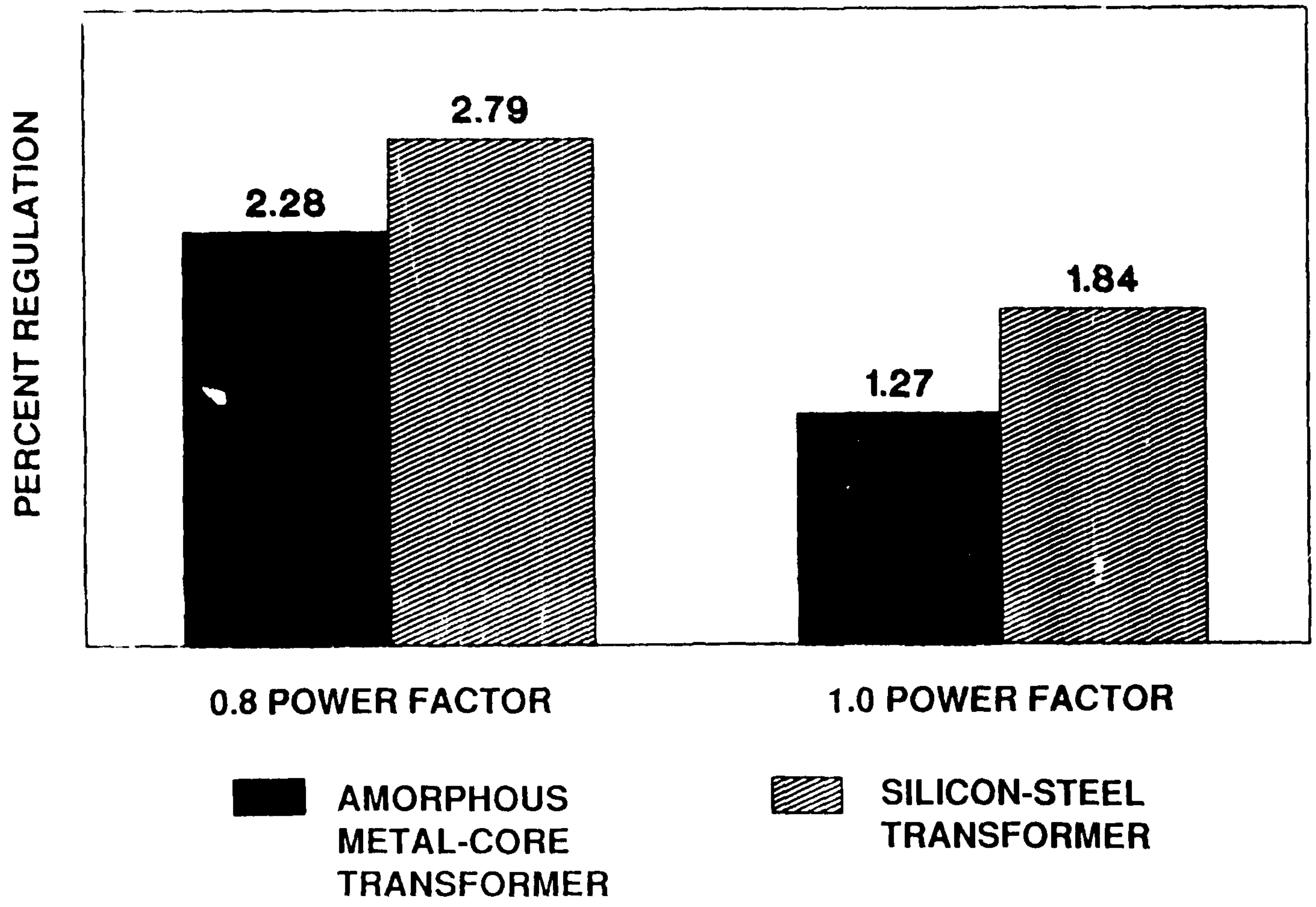

Figure 12. Percent regulation at 100% load.

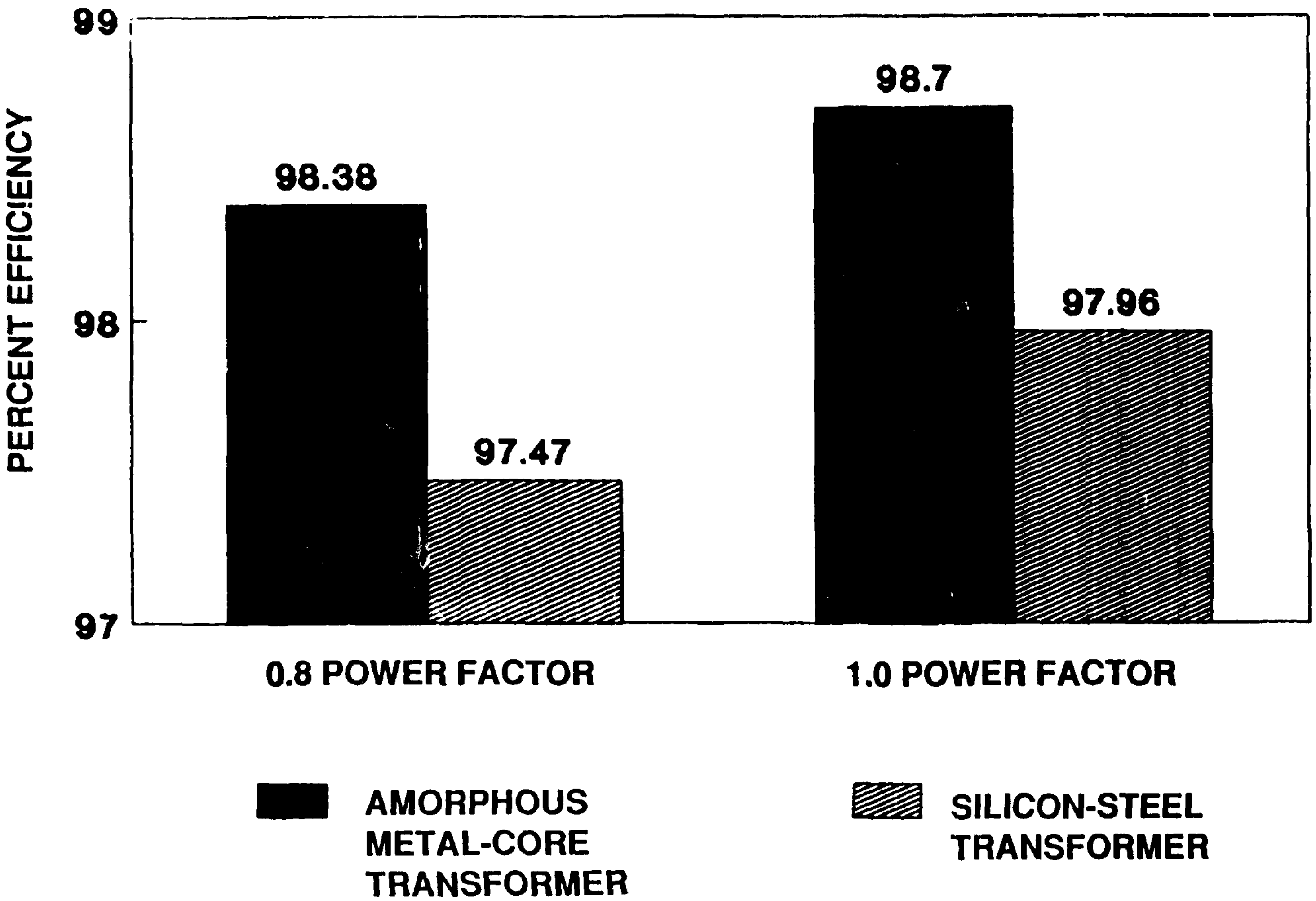

Figure 13. Percent efficiency at 100% load.

Appendix A

SUMMARY OF PHASE I TEST RESULTS FOR
25-kVA AMORPHOUS METAL-CORE TRANSFORMERS

TEST RESULTS FOR GENERAL ELECTRIC AMORPHOUS METAL CORE 25 KVA TRANSFORMERS

TRANSFORMER SERIAL NO. >	AMORPHOUS TRANSFORMERS AFTER INITIAL TESTS UPON RECEIPT P217059-Y2A	P217060-Y2A	P217061-Y2A	AMORPHOUS TRANSFORMERS AFTER 170% TEMPERATURE RISE TEST P217060-Y2A	P217061-Y2A	AMORPHOUS TRANSFORMER AFTER SHORT-CIRC, SOUNDS RIV TEST P217059-Y2A	AMORPHOUS TRANSFORMER AFTER 4HR SHAKE TEST P217059-Y2A	AMORPHOUS TRANSFORMER AFTER 4 FT DROP TEST P217059-Y2A	AMORPHOUS TRANSFORMER AFTER COLD-LOAD PICKUP P217061-Y2A	AMORPHOUS TRANSFORMER AFTER SATUR & EFFICIENCY P217061-Y2A	GI STEEL TRANSFORMER AFTER SATUR &EFFICIENCY P239216-Y00
TESTS CONDUCTED											
RATIO	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
POLARITY	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
FULL WAVE IMPULSE	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
APPLIED POTENTIAL-HLIC	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
APPLIED POTENTIAL-LHIC	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
INDUCED POTENTIAL-400 Hz	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
NO-LOAD LOSS (WATTS)	19.400	17.100	18.800	18.300	18.300	19.300	19.200	18.800	18.600	17.100	67.000
% EXCITING CURRENT	0.097	0.212	0.170	0.240	0.200	0.098	0.097	0.110	0.180	0.170	0.820
% EFFICIENCY @ PF=1.0	98.700	98.700	98.700	98.600	98.600	98.600	98.700	98.600	98.700	98.700	98.000
% EFFICIENCY @ PF=0.8	98.400	98.400	98.300	98.300	98.300	98.300	98.300	98.300	98.300	98.300	97.500
HV RESISTANCE (OHMS)	3.344	4.584	4.609	4.692	4.732	4.652	4.632	4.662	4.622	4.682	6.342
LV RESISTANCE (OHMS)	0.017	0.013	0.013	0.014	0.013	0.013	0.013	0.013	0.013	0.013	0.019
I SQUARED R LOSS (WATTS)	306.910	308.340	306.100	317.500	315.700	313.900	313.200	315.300	308.400	312.800	437.900
STRAY LOSSES (WATTS)	8.890	10.030	10.800	9.500	10.300	10.100	3.800	8.700	10.600	10.200	13.100
LOAD LOSS (WATTS)	315.800	318.300	316.900	327.000	326.000	324.000	317.000	324.000	319.000	323.000	451.000
TOTAL LOSS (WATTS)	335.200	335.400	335.700	345.300	344.300	343.300	336.200	342.800	337.600	340.100	518.000
% RESISTANCE	1.260	1.270	1.270	1.310	1.300	1.300	1.270	1.300	1.280	1.290	1.800
% REACTANCE	2.090	2.100	2.110	2.120	2.120	2.220	2.150	2.210	2.120	2.130	2.230
% IMPEDANCE	2.440	2.460	2.460	2.490	2.490	2.570	2.500	2.560	2.480	2.490	2.870
% REGULATION @ PF=1.0	1.280	1.290	1.290	1.330	1.330	1.320	1.290	1.320	1.300	1.310	1.830
% REGULATION @ PF=0.8	2.270	2.280	2.290	2.320	2.320	2.370	2.310	2.370	2.300	2.320	2.700

TRANSFORMER SERIAL NO. >	PERCENT (%) CHANGE IN AMORPHOUS TRANSFORMER PARAMETERS AFTER 170% TEMPERATURE RISE TEST P217060-Y2A	P217061-Y2A	%CHANGE IN AMORPHOUS TRANSFORMER PARAMETERS AFTER SHORT-CIRC, SOUNDS RIV TEST P217059-Y2A	% CHANGE IN AMORPHOUS TRANSFORMER PARAMETERS AFTER 4HR SHAKE TEST P217059-Y2A	% CHANGE IN AMORPHOUS TRANSFORMER PARAMETERS AFTER 4 FT DROP TEST P217059-Y2A	% CHANGE IN AMORPHOUS TRANSFORMER PARAMETERS AFTER COLD-LOAD PICKUP P217061-Y2A	% CHANGE IN AMORPHOUS TRANSFORMER PARAMETERS AFTER SATUR & EFFICIENCY P217061-Y2A
TESTS CONDUCTED							
RATIO	PASS	PASS	PASS	PASS	PASS	PASS	PASS
POLARITY	PASS	PASS	PASS	PASS	PASS	PASS	PASS
FULL WAVE IMPULSE	PASS	PASS	PASS	PASS	PASS	PASS	PASS
APPLIED POTENTIAL-HLIC	PASS	PASS	PASS	PASS	PASS	PASS	PASS
APPLIED POTENTIAL-LHIC	PASS	PASS	PASS	PASS	PASS	PASS	PASS
INDUCED POTENTIAL-400 Hz	PASS	PASS	PASS	PASS	PASS	PASS	PASS
NO-LOAD LOSS (WATTS)	7.010	-2.660	-0.515	-1.031	-3.093	-1.064	-9.043
% EXCITING CURRENT	13.700	17.647	1.031	-0.206	13.402	3.882	0.000
% EFFICIENCY @ PF=1.0	-0.101	-0.101	-0.101	0.000	-0.101	0.000	0.000
% EFFICIENCY @ PF=0.8	-0.102	0.000	-0.102	-0.102	-0.102	0.000	0.000
HV RESISTANCE (OHMS)	2.367	2.666	39.107	38.500	39.406	0.200	1.502
LV RESISTANCE (OHMS)	3.640	3.676	-22.234	-21.631	-21.631	1.345	2.099
I SQUARED R LOSS (WATTS)	2.971	3.136	2.278	2.069	2.734	0.751	2.189
STRAY LOSSES (WATTS)	-5.204	-4.630	13.611	-57.255	-2.137	-1.052	-5.556
LOAD LOSS (WATTS)	2.733	2.072	2.597	0.380	2.597	0.663	1.925
TOTAL LOSS (WATTS)	2.952	2.562	2.416	0.298	2.267	0.566	1.311
% RESISTANCE	3.150	2.362	3.175	0.794	3.175	0.787	1.575
% REACTANCE	0.952	0.474	6.220	2.871	5.742	0.474	0.948
% IMPEDANCE	1.220	1.220	5.328	2.459	4.918	0.813	1.220
% REGULATION @ PF=1.0	3.101	3.101	3.125	0.781	3.125	0.775	1.550
% REGULATION @ PF=0.8	1.754	1.310	4.405	1.762	4.405	0.437	1.310
AVERAGE % CHANGE IN NO-LOAD LOSS, LOAD LOSS, EFFICIENCY, & REGULATION:	2.401	0.754	1.568	0.298	1.139	0.135	-0.710
MAXIMUM % CHANGE IN NO-LOAD LOSS, LOAD LOSS, EFFICIENCY, & REGULATION:	7.010 NO-LOAD WATTS	3.101 % REGULATION	4.405 % REGULATION	1.762 % REGULATION	4.405 %REGULATION	0.775 % REGULATION	1.925 LOAD LOSS

Appendix B

WESTINGHOUSE ELECTRIC CORPORATION ENGINEERING REPORT NO. 87-11

Reliability Testing of General Electric Amorphous Metal Distribution Transformers

PROPRIETARY CLASS III - Unlimited Distribution

DTD ENGINEERING REPORT #87-11

Reliability Testing of 25 kVA General Electric Amorphous Metal Distribution Transformers

By

G.V. Jones

G. V. Jones

March 19, 1987

APPROVED: D. W. Whitley
D. W. Whitley
Mgr., ACT Product Engineering

APPROVED: David W McElroy 3/26/87
D. W. McElroy
Division Engineering Mgr.

APPROVED: R R Schrieber
R. R. Schrieber
ACT Project Manager

WESTINGHOUSE ELECTRIC CORPORATION
DISTRIBUTION TRANSFORMER DIVISION
ATHENS, GEORGIA

March 20, 1987

I certify that the attached Engineering Report #87-11 is an accurate summary of the testing done on three General Electric amorphous distribution transformers and two General Electric silicon steel transformers provided by N.C.E.L..

The tests which are specified by either ANSI or NEMA standards were done in accordance with those standards. The other tests were done in accordance with the N.C.E.L. statement of work. In the case of the drop test, the height was changed from 3 feet to 4 feet at the request of N.C.E.L. personnel witnessing the tests.

Samuel L. Carter Jr

Samuel L. Carter, Jr., P.E.
Engineering
Westinghouse Electric Corporation

I. INTRODUCTION

"The United States Naval Civil Engineering Laboratory (N.C.E.L.) engineers are evaluating amorphous metal transformers as emerging new technology to reduce electric baseload power consumption and as a PCB transformer replacement." As part of this evaluation, the N.C.E.L. contracted with the Westinghouse Distribution Transformer Division (DTD) to test and evaluate three 25 kVA General Electric amorphous metal transformers (N.C.E.L. Requisition #N68305-6339-7731). Two 25 kVA General Electric silicon steel transformers were provided for comparison testing. All transformers were provided by N.C.E.L. and were returned to N.C.E.L. following test and evaluation. In January 1987, Westinghouse DTD began a rigorous test program to determine the viability of amorphous metal transformers for Naval use. This report contains the results of that testing program.

II. CONCLUSIONS/RECOMMENDATIONS

The three amorphous metal transformers tested and evaluated by DTD passed all tests. Amorphous metal transformers with wound cores are a viable product and functionally suitable for applications such as reducing electric baseload power consumption and replacing PCB transformers.

III. EXPERIMENTAL PROCEDURE/RESULTS

A list is given in Table 1 of the tests performed on the transformers with amorphous metal cores. Some tests were also performed on transformers with silicon steel cores for comparison purposes. These tests are also listed in Table 1. The test sequence for the transformers is given in Table 2. Finally, the test descriptions and results are given in Sections 1 through 11.

TABLE 1. TESTS PERFORMED

	25 kVA 75 kV BIL Amorphous Metal Test Status	25 kVA 75 kV BIL Silicon Steel Test Status	Test Results/ Description Section
ANSI "ROUTINE" TESTS			
Ratio	P	P	1
Polarity	P	P	1
HLIC	P	P	1
LHIC	P	P	1
400 HZ	P	P	1
No-Load Loss/Exciting Current	C	C	1
ANSI "DESIGN" TESTS			
Full Wave Impulse	P	P	1
Chopped Wave Impulse	*	X	6
Winding Resistance	C	C	1
Impedance/Load Loss	C	C	1
Temperature Rise	P	P	2
Sound Level	P	X	3
ANSI "OTHER" TESTS			
Radio Influence Voltage (RIV)	P	X	4
Short Circuit	P	X	5
ADDITIONAL TESTS **			
Front of Wave Impulse	*	X	6
Full Wave Impulse-Energized	P	X	7
Chopped Wave Impulse-Energized	P	X	7
Front of Wave Impulse-Energized	P	X	7
Safe Transit Test (Shake & Drop)	P	X	8
Infrared Scanning-Energized	C	C	9
Cold Load Pickup	P	X	10
Saturation Curves	C	C	11
Regulation & Efficiency	C	C	11

P = Passed Test
F = Failed Test
C = Testing Completed - No Pass/Fail Criteria Available
* = See Same Test With Unit Energized
Q = Qualified Pass
X = This Test Not Part of Test Program for Silicon Steel Units
** = These Tests are not defined or required by ANSI and/or NEMA Standards. These tests were defined by mutual agreement with N.C.E.L. and specified in the Statement of Work (pages 3, 4 & 5 of Requisition #N68305-6339-7731) provided by N.C.E.L.

TABLE 2. TRANSFORMER TEST SEQUENCES

Amorphous Metal Transformers			Silicon Steel Transformers	
Serial Numbers			Serial Numbers	
P217059-YZA	P217060-YZA	P217061-YZA	P239216-YOB	P239217-YOB
*Commercial Tests	RIV	RIV	Infrared Scan	100% Temp Rise
Short Circuit	Commercial Tests	Commercial Tests	100% Temp Rise	150% Temp Rise
Sound Level	100% Temp Rise	100% Temp Rise	150% Temp Rise	Commercial Test
RIV	170% Temp Rise	170% Temp Rise	Commercial Test	
Commercial Tests	Commercial Tests	Commercial Tests	Regulation Tests	
Shake Test	Δ Impulse Energized	Cold Load Pick Up	Efficiency Tests	
Commercial Tests	Infrared Scan	Commercial Tests	Saturation Curves	
Drop Test		Regulation Tests	Commercial Tests	
Commercial Tests		Efficiency Tests		
Autopsy		Saturation Curves		
		Commercial Tests		

* Commercial Tests Include: Ratio, Polarity, Full Wave Impulse, Applied Potential (HV Winding (HLIC) & LV Winding (LHIC)), Induced Potential (400 Hz), NL Loss/Exciting Current, Winding Resistance, and Impedance/Load Loss.

Δ Impulse Energized Tests Include (in order): Reduced Full Wave, Chopped Wave, 400 Hz, Front of Wave, 400 Hz, Full Wave, 400 Hz, HLIC & LHIC.

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TEST DESCRIPTIONS AND RESULTS

1. Distribution Transformer Division (DTD) Standard Tests

Ratio per ANSI C57.12.90-1980 Sec. 7
Polarity per ANSI C57.12.90-1980 Sec. 6
Full Wave Impulse per ANSI C57.12.90-1980 Sec. 10.5
Applied Potential (HIIC & LHIC) per ANSI C57.12.90-1980 Sec. 10.3
Induced Potential (400 Hz) per ANSI C57.12.90-1980 Sec. 10.4
NL Loss/Exciting Current per ANSI C57.12.90-1980 Sec. 8
Impedance/Load Loss per ANSI C57.12.90-1980 Sec. 9

These commercial tests are performed on each DTD transformer before it is shipped. In general the tests indicate the degree of consistency of manufacturing procedures and processes and serve as a check on the quality of the transformers. The amorphous metal transformers were commercially tested upon receipt and at other times during the test sequence when required. The amorphous metal transformers all passed the "as received" commercial tests (see Appendix A.1 for test reports).

2. Temperature Rise

Per ANSI C57.12.90-1980 Sec. 11

One coil of amorphous metal transformer P217059-YZA was sectioned to determine HV and LV conductor cross-sectional areas. These cross-sectional areas were used in the calculation of the LV and HV winding temperature rises for the amorphous metal transformers according to ANSI C57.12.90-1980 Sec. 11.3.1.1. For the silicon steel transformers at 100% load, the LV and HV winding temperature rises were calculated assuming winding load losses less than 14 watts/lb. and using a 1°C/minute after shutdown correction according to ANSI C57.12.90-1980 Sec. 11.3.1.1. For the silicon steel transformers at 150% load, the winding temperature rises were calculated using the cooling curve method according to ANSI C57.12.90-1980 Sec. 11.3.1.2.

Test results at 100% load were (test reports in Appendix A.2):

Serial Number	Core Material	Top Oil Rise (°C)	HV Winding Rise (°C)	LV Winding Rise (°C)
P217060-YZA	AM	39.1	48.9	47.5
P217061-YZA	AM	39.4	51.7	50.4
P239216-Y0B	Silicon St.	53.7	60.2	58.8
P239217-Y0B	Silicon St.	52.1	59.6	60.8

All of the above units operated under the ANSI 65°C temperature rise limit. The amorphous metal (AM) units operated at lower temperatures than the silicon steel units. The temperature rises are a function of the losses of the core/coil as well as the cooling surface of the tank. Amorphous metal core/coils tend to be physically larger than silicon steel core/coils with the same design value for losses. The amorphous metal units may be in larger diameter tanks, as was the case here, and therefore may tend to have lower temperature rises.

It was also planned to make temperature rise measurements on the above units at 170% load (not a required ANSI test). It was not possible to test the silicon steel units at 170% load because the oil temperature would have exceeded the flashpoint. Therefore, the silicon steel units were tested at 150% load. Test results were (test reports in Appendix A.2):

Serial Number	Core Material	Load	Top Oil Rise (°C)	HV Winding Rise (°C)	LV Winding Rise (°C)
P217060-YZA	AM	170%	101.7	127.5	122.4
P217061-YZA	AM	170%	101.7	129.2	123.4
P239216-Y0B	Silicon St.	150%	102.1	120.6	112.5
P239217-Y0B	Silicon St.	150%	99.8	118.8	110.2

The above units passed commercial tests following temperature rise testing (test reports in Appendix A.2).

3. Sound Level

Per ANSI C57.12.90-1980 Sec. 13
ANSI/IEEE Std. 141-1986
NEMA TR1-1980

Sound level tests were performed on an amorphous metal transformer after it was subjected to short circuit testing (see Section 5). The sound level measurements represented "worst case" conditions, since short circuit testing could increase sound level by loosening and/or fracturing core laminations if it were possible to do so.

Transformer P217059-YZA had a sound level of 32.4 dB(A) at 100% rated voltage (very low - only 0.1 dB(A) greater than semi-anechoic chamber) and 37.3 dB(A) at 110% rated voltage. The sound level measured at 100% voltage is well below the NEMA limit of 48 dB(A). There is no ANSI limit on the sound level at 110% voltage. The test report is included in Appendix A.3.

4. Radio Influence Voltage (RIV)

Per NEMA TR1-1980 Revision 2 Sec. 0.03 (Limits)
7.01 (Test Code)
107-1964 Reaffirmed 1981 (Test Methods)

Amorphous metal transformers P217059-YZA, P217060-YZA, and P217061-YZA produced no RIV at 100% or 110% rated voltage (test record in Appendix A.4).

5. Short Circuit

Per ANSI C57.12.90-1980 Sec. 12

The short circuit test results on amorphous metal transformer P217059-YZA are:

SC Current X Rated	% Z Change/ Limit	% Io Change/ Limit	Inrush Current X Normal 1st Peak	6th Peak
40	*5.3/11.1	*1.0/25	28.8	12.8

* As determined from before and after (W) standard commercial tests.

This transformer passed the short circuit test. Standard commercial tests following the short circuit test and an autopsy of the transformer revealed no damage attributable to short circuit testing. Short circuit and standard commercial test results are in Appendix A.5.

Magnetizing inrush current tests were also done on this unit (see above results). There are no industry standards on magnetizing inrush current tests. The magnetizing inrush current measurements were made under conditions which should have resulted in maximum peak inrush current.

6. Chopped Wave and Front of Wave Impulse

Per ANSI C57.12.90-1980 Sec. 10.5

Note that front of wave impulse is not a defined ANSI test for distribution transformers.

In order to increase the severity of these tests, they were performed with the transformer energized at rated voltage. See "Impulse Tests With Unit Energized", Section 7.

7. Impulse Tests with Unit Energized

Per ANSI C57.12.90-1980 Sec. 10.5 except with unit energized at rated voltage.

These experimental tests, which are neither required nor defined by ANSI, check the insulation strength of the transformer under simulated field operating conditions.

First, amorphous metal transformer P217060-YZA received a reduced full wave impulse on each HV bushing to generate "baseline" waveforms for comparison with full wave impulse waveforms to be generated at the end of the test. Then the transformer passed 88 kV (1.6 μsec to chop) chopped wave impulse and 135 kV (.5 μsec to chop) front of wave impulse tests. To doublecheck the chopped wave and front of wave oscilloscope indications, the unit received and passed induced voltage (400 Hz) tests after the chopped wave and after the front of wave tests.

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Next the transformer received the 75 kV full wave impulse test. The oscilloscope figures (see Appendix A.7) revealed two anomalies in the wave shapes produced by full wave impulse. First, the full wave tails rose above the reference line (Figures A.7.4A and A.7.4B) while the normal reduced wave tails rose to the reference line (Figures A.7.1A and A.7.1B). Second, the full wave in Figure 4A had a "kink" halfway between the peak and the reference line while the normal reduced wave had a "smooth" curve from the peak to the reference line. To determine if the anomalies signaled a failure in the insulation, the unit was given an induced voltage (400 Hz) test and applied voltage tests (HLIC and LHIC). The unit passed both of these auxillary tests and was considered as having passed the full wave impulse test. To conclude, the unit passed chopped wave, front of wave, and full wave impulse tests with the unit energized at rated voltage. The test record is in Appendix A.7.

8. Safe Transit

Safe transit tests include a shake test (4 hours on the safe transit machine at 160 rpm) and a drop test (4 feet onto a hard surface). The drop test was changed from 3 feet as specified in the N.C.E.L. Statement of Work to 4 feet at the request of N.C.E.L. personnel witnessing the test. The shake test is designed to simulate a transformer traveling twice the distance from the east coast to the west coast in a transfer truck. The drop test is designed to simulate a transformer being improperly unloaded from the back of a utility truck. To pass the safe transit test, the transformer must complete the shake and drop tests with less than or equal to a 10% increase in no-load watts. The transformer also must pass DTD standard commercial tests after the shake test and after the drop test.

Amorphous metal transformer P217059-YZA was safe transit tested. The shake test resulted in no change in no load watts and the drop test resulted in a 3% decrease in no load watts. The transformer passed standard commercial tests after the shake and drop tests. The unit passed the safe transit test. Test records and reports are in Appendix A.8.

After the safe transit test, the unit was autopsied. During the autopsy, some mechanical damage was found such as a bent and distorted tank bottom, bowed core/coil top frame, and cracked core/coil pressure plates. This type of damage was not considered unusual in a 25 kVA transformer dropped from a height of four feet. Amorphous metal particles were discovered outside the core assembly. Specifically, they were found in the bottom of the tank, on the inside of the bottom frame (see Figure 1) and on the coils. Even though the unit passed the safe transit test and subsequent commercial tests, the presence of amorphous metal particles in the oil environment could lower the dielectric strength of the oil and/or reduce the insulation margin of the coil. This could be a greater concern in transformers operating at higher voltages than this one, and could be expected to play a more important role as the insulation system ages.

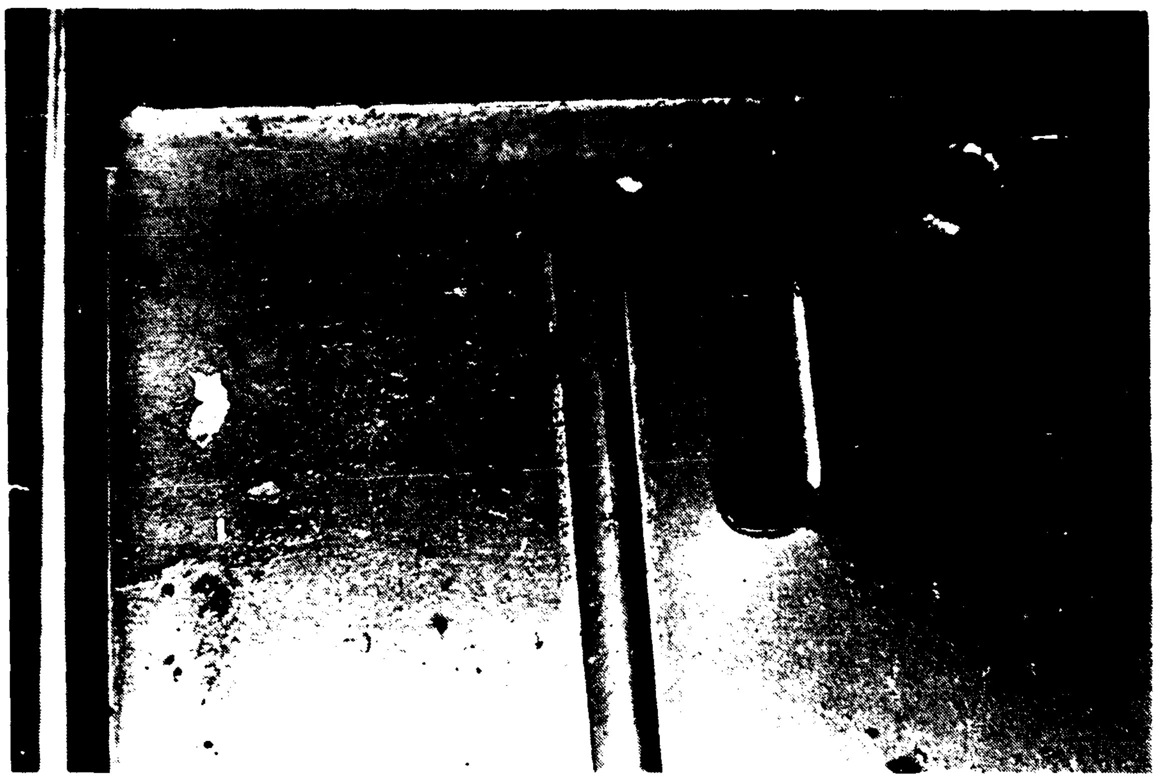

Figure 1. Amorphous Metal Particles Inside Bottom Frame

9. Infrared Scanning

An amorphous metal transformer P217060-YZA and a silicon steel transformer P239216-YOB were energized at various voltages and observed with infrared imaging equipment. The observations were recorded on a video cassette tape which was given to the N.C.E.L. This service was performed by Pedascan Inc. of Foristell, Missouri. Infrared imaging gives a visual indication of the relative amounts of energy required to magnetize the different cores

10. Cold Load Pickup

A cold load pickup test was conducted on an amorphous metal transformer P217061-YZA. This test was designed to simulate the following conditions:

1. Power outage in cold (≈-35°C) environment.

2. Replacement transformer brought from cold (≈-35°C) warehouse to restore service.

3. When service is restored, everyone turns on heat, appliances, etc. This puts a heavy load on a very cold transformer with oil viscosity much higher than normal.

The purpose of the test was to determine if the above conditions would have any injurious effect, such as thermal instability, on the transformer's operation.

For the test, the unit was placed in a cold chamber at -38°C. After the transformer oil reached -34°C, the unit was energized at 200% load (LV winding shorted). Watt loss was measured for the next 2 hours. The load was then reduced to 100% and watt losses were measured each hour for the next 6 hours (test report in Appendix A.10.).

There was no indication of thermal instability. Further, the unit passed all commercial tests (test report in Appendix A.10.) following the cold load pickup test. To conclude, the transformer performed satisfactorily during the cold load pickup test.

11. Saturation/Regulation/Efficiency

Temperature Rise Tests per ANSI C57.12.90 - 1980 Sec. 11
Saturation Curves per ANSI C57.12.90 - 1980 Sec. 8
Regulation Calculations per ANSI C57.12.90 - 1980 Sec. 14.4
Efficiency Calculations per ANSI C57.12.90 - 1980 Sec. 14.3

50%, 100%, and 150% load temperature rise tests were done on amorphous metal transformer P217061-YZA and silicon steel transformer P239216-YOB to obtain the data needed to plot percent regulation and percent efficiency versus percent load (see Appendix A.11 for temperature rise test records). Immediately after "shutdown" of each temperature rise test, no-load loss/excitation current measurements were made to obtain saturation curves for 50%, 100%, and 150% loading conditions.

Saturation, regulation, and efficiency are functions of transformer design parameters such as core design induction, core material, number of low voltage winding turns, low and high voltage conductor sizes and materials, etc. A comparison of the saturation, regulation, and efficiency of an amorphous metal versus a standard silicon steel transformer (based on units supplied by N.C.E.L.) yields the following conclusions:

1. From Tables A.11.1 through A.11.8 and Figures A.11.3 and A.11.4 (see Appendix A.11), the exciting current of the amorphous metal transformer is less than the exciting current of the silicon steel transformer for loads up to 150% and voltages up to 110% of rated nameplate voltage.

2. From Tables A.11.9 and A.11.10 and Figures A.11.5 and A.11.6 (see Appendix A.11), the percent regulation of the amorphous metal transformer is less than the percent regulation of the silicon steel transformer for loads up to 150% and voltages up to 110% of rated nameplate voltage at power factors of unity and 0.8 lagging.

3. From Tables A.11.11 and A.11.12 and Figures A.11.7 and A.11.8 (see Appendix A.11), the percent efficiency of the amorphous metal transformer is greater than the percent efficiency of the silicon steel transformer for loads up to 150% and voltages up to 110% of rated nameplate voltage at power factors of unity and 0.8 lagging.

   Both transformers passed all commercial tests (see Appendix A.11 for test reports) following the saturation/regulation/efficiency tests.

APPENDIX A.1

AS RECEIVED DTD STANDARD COMMERCIAL TEST REPORTS

WESTINGHOUSE DTC COMMERCIAL TEST REPORT

DATE:01/05/87

CONDITION: AS RECEIVED

STYLE: G.E. 25kVA AMORPHOUS METAL POLE TYPE

LV: 120/240 HV: 4160; 75kV BIL SERIAL #:P217059-YZA

RATIO	PASS	* HV RESISTANCE (OHMS)	3.3442
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.017154
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	306.91
APPLIED POTENTIAL - HLIC	PASS	* STRAYS	8.89
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	315.8
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	335.2
NL LOSS (WATTS)	19.4	* % RESISTANCE	1.26
% EXCITING CURRENT	0.097	* % REACTANCE	2.09
% EFFICIENCY @ PF=1	98.7	* % IMPEDANCE	2.44
% EFFICIENCY @ PF=.8	98.4	% REGULATION @ PF=1	1.28
		% REGULATION @ PF=.8	2.27

TEST ENGINEER: Gregg V. Jones

GREGG V. JONES

* CORRECTED TO 85 DEGREES C

WESTINGHOUSE DTD COMMERCIAL TEST REPORT DATE:01/16/87

CONDITION: AS RECEIVED

STYLE: G.E. 25kVA AMORPHOUS METAL POLE TYPE

LV: 120/240 HV: 4160; 75kV BIL SERIAL #:P217060-YZA

RATIO	PASS	* HV RESISTANCE (OHMS)	4.5835
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.013161
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	308.24
APPLIED POTENTIAL - HLIC	PASS	* STRAYS	10.03
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	318.3
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	335.4
NL LOSS (WATTS)	17.1	* % RESISTANCE	1.27
% EXCITING CURRENT	0.212	* % REACTANCE	2.1
% EFFICIENCY @ PF=1	98.7	* % IMPEDANCE	2.45
% EFFICIENCY @ PF=.8	98.4	% REGULATION @ PF=1	1.29
		% REGULATION @ PF=.8	2.28

TEST ENGINEER: Gregg V. Jones

GREGG V. JONES

* CORRECTED TO 85 DEGREES C

WESTINGHOUSE DTD COMMERCIAL TEST REPORT — DATE: [illegible]

CONDITION: AS RECEIVED

STYLE: G.E. 25KVA AMORPHOUS METAL POLE TYPE

LV: [illegible] HV: [illegible] 75KV BIL SERIAL #: [illegible]

RATIO	PASS	* HV RESISTANCE (OHMS)	4.6071
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.012967
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	[illegible]
APPLIED POTENTIAL - HLID	PASS	*STRAYS	10.5
APPLIED POTENTIAL - LHID	PASS	* LOAD LOSS (WATTS)	[illegible]
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	[illegible]
NL LOSS (WATTS)	18.3	* % RESISTANCE	[illegible]
% EXCITING CURRENT	[illegible]	* % REACTANCE	[illegible]
% EFFICIENCY @ PF=1	[illegible]	* % IMPEDANCE	[illegible]
% EFFICIENCY @ PF=.8	[illegible]	% REGULATION @ PF=1	[illegible]
		% REGULATION @ PF=.8	[illegible]

TEST ENGINEER: Gregg V. Jones
GREGG V. JONES

* CORRECTED TO 85 DEGREES C

APPENDIX A.2

TEMPERATURE RISE TEST REPORTS

WESTINGHOUSE FORM 4667K

DTD LAB PAGE Nº 00725

TRANSFORMER TYPE: Pole TEMPERATURE TEST ON 25 K.V.A. TRANSFORMER STYLE Gen Electric

CONNECTED H.V. 4160 VOLTS L.V. 120/240 VOLTS

LOAD H.V. 100% 6.00 AMPS. L.V. 104 AMPS 60 CYCL

WATTS PER LB. H.V. 7.58 ? L.V. ? 5.78 MAGNETIZED VOLTS CYCLES ON

GALLONS OIL CIRCUIT TEST METHOD Back NO. OF RADIATORS 0 NO. TUBES 0

REMARKS 1) Amorphous metal cores
2) Test for Navy

SERIAL # ACTP217060

TIME AFTER SHUTDOWN MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	* OHMS	TEMP. BY RES.	CORRECTION TO SHDN.	AVE. WIND. TEMP.
		25.5	3740	.001	3.735			
1	25		4504	"	4.499	76.74	0.72	77.46

TEMP. H.V. WINDING BY RESISTANCE (above)

TIME AFTER SHUTDOWN MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.
		25.5	(.01+.00085)×1		.01085		
2	40		(.01+.0030)×1		.01300	75.13	0.90

TEMP. L.V. WINDING BY RESISTANCE (above)

CALC. H.V. WINDING RISE 77.46 - 67.7 = 9.76°C DIFF / 77.46 - 28.6 = 48.86 winding rise

CALC. L.V WINDING RISE 76.13 - 67.7 = 8.43°C DIFF / 76.13 - 28.6 = 47.53 winding rise

HOURS	TIME	TEMPERATURE READINGS TOP OIL	BTTM. OIL				AMB. OIL	TEMPERATURE RISE TOP OIL	BTTM. OIL	WATTMETER AND VOLTMETER
Steady State		67.7					28.6	39.1		

Meters (across 2 transformers)

	Ammeter	Wattmeter	Voltmeter
Start up -	6amps (3×2)	526 (65.75×2×4)	196 (49×4)
Shutdown -	6amps	616	204

LOAD TEST AT ____ °C

AMPS

VOLTMETER

WATTMETER

NO LOAD TEST

(T.W.) WATTMETER

(A.W.) VOLTS ____ X AMPS ____ =

____ VA

TIME CONSTANT

63.3 x 39.1 °C OIL RISE = 24.75

TIME CONSTANT = 6 HRS. 15 MIN.

.075×.139 or .102 round

AL TYPE CONDUCTOR H.V. nameplate

AL TYPE CONDUCTOR L.V. nameplate

.018×9

CALCULATED COMPROMISE CURRENT not used

OTHER REMARKS

Rear unit in back config

* .005 Ω bridge leads

WATTS PER LB at steady state

$$\left(\frac{.00379 \times I^2}{A}\right)^2 \cdot \frac{225+\theta}{310}$$

$A = \frac{\pi}{4}(\text{dia})^2$ or th × width of con

θ = winding temp. at shutdown

TEST REQUESTED BY Greg Jones DATE TESTED 2-4-87 BY Bill Belvan L.SPEC. #

TRANSFORMER TYPE: Pole TEMPERATURE TEST ON 25 K.V.A. TRANSFORMER STYLE Gen Electric

CONNECTED H.V. 4160 (taps) VOLTS L.V. 120/240 VOLTS

LOAD H.V. 100% 6.00 AMPS. L.V. 104 AMPS. 60 CYCL

WATTS PER LB. H.V. 7.65 ? L.V. 5.84? MAGNETIZED ____ VOLTS ____ CYCLES ON ____

GALLONS OIL ____ CIRCUIT TEST METHOD Back NO. OF RADIATORS 0 NO. TUBES 0

REMARKS 1) Amorphous metal Cores

2) tests for Navy SERIAL # ACT P217061

TIME AFTER SHUTDOWN MIN.	SEC.	TEMP. H.V. WINDING BY RESISTANCE AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.	AVE. WIND. TEMP.	TIME AFTER SHUTDOWN MIN.	SEC.	TEMP. L.V. WINDING BY RESISTANCE AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.
		25.5	3750	x.001	3.745						25.5	(.01+.00050)	x1	.01050		
1	59		4554	"	4.549	79.28	1.0+	80.28	3	09		(.01+.0027)	x1	.01270	77.98	1.02

CALC. H.V. WINDING RISE 80.28 - 68 = 12.28°C DIFF / 80.28 - 28.6 = 51.68°C winding rise

CALC. L.V. WINDING RISE 79.0 - 68.0 = 11.0°C DIFF / 79.0 - 28.6 = 50.4°C winding rise

HOURS	TIME	TEMPERATURE READINGS TOP OIL	BTTM. OIL				AMB. OIL	TEMPERATURE RISE TOP OIL	BTTM. OIL				WATTMETER AND VOLTMETER
Steady State		68.0					28.6	39.4					

LOAD TEST AT ____ °C

AMPS ____

VOLTMETER ____

WATTMETER ____

NO LOAD TEST

(T.W.) WATTMETER ____

(A.W.) VOLTS ____ X AMPS ____ = ____ VA

TIME CONSTANT

63.3 x 39.4 °C OIL RISE = 24.95

TIME CONSTANT = 6 HRS. 15 MIN.

.075 x .139 or .102 dia

AL TYPE CONDUCTOR H.V. nameplate

AL TYPE CONDUCTOR L.V. nameplate

.018 x 9

CALCULATED COMPROMISE CURRENT Not used

OTHER REMARKS

front unit in back config

* .005 Ω bridge leads)

TEST REQUESTED BY Greg Jones DATE TESTED 2-4-87 BY Bill Belvan L.SPEC # ____

7 B. BELVAN ATHENS BACK-BACK AMOR. CORES 25KVA 4160V 240 GREG JONES 05 FEB 87 F.I.(?) AND 60 (REAR) 100 PCT

0036 700	01 AMB	02 AMB	03 AMB	04 AVER.	05 61 TOP	06 RISE	07 60 TOP	08 RISE	09	10	11	12	13	14	15	
08:00:00	27.4C	25.8C	26.8C	26.6	26.3C	-0.3	26.4C	-0.2								
08:15:00	27.8C	25.8C	26.8C	26.8	26.4C	-0.4	[illegible]	-0.2								
08:30:00	28.4C	25.8C	26.8C	27.0	27.3C	0.3	27.6C	0.6								Start
08:45:00	28.2C	25.8C	26.9C	26.9	28.6C	1.7	28.9C	2.0								
09:00:00	28.2C	25.9C	26.9C	27.0	30.0C	3.0	30.3C	3.3								
09:15:00	28.5C	25.9C	26.9C	27.1	31.4C	4.3	31.7C	4.6								
09:30:00	28.5C	25.9C	27.0C	27.1	32.8C	5.7	33.2C	6.1								
09:45:00	28.6C	26.0C	27.1C	27.2	34.2C	7.0	34.6C	7.4								
10:00:00	28.6C	26.0C	27.1C	27.2	35.5C	8.3	35.9C	8.7								
10:15:00	28.5C	26.1C	27.2C	27.2	36.8C	9.6	37.1C	9.9								
10:30:00	28.6C	26.1C	27.2C	27.3	38.0C	10.7	38.3C	11.0								
10:45:00	28.7C	26.2C	27.3C	27.4	39.1C	11.7	39.4C	12.0								
11:00:00	28.7C	26.2C	27.3C	27.4	40.2C	12.8	40.5C	13.1								
11:15:00	28.7C	26.3C	27.4C	27.4	41.3C	13.9	41.6C	14.2								
11:30:00	28.9C	26.3C	27.4C	27.5	42.3C	14.8	42.6C	15.1								
11:45:00	28.7C	26.4C	27.5C	27.5	43.3C	15.8	43.5C	16.0								
12:00:00	28.5C	26.4C	27.6C	27.5	44.3C	16.8	44.5C	17.0								
12:15:00	28.8C	26.5C	27.7C	27.6	45.2C	17.6	45.4C	17.8								
12:30:00	28.8C	26.5C	27.7C	27.6	46.0C	18.4	46.2C	18.6								
12:45:00	28.8C	26.6C	27.8C	27.7	46.9C	19.2	47.2C	19.5								
13:00:00	28.9C	26.6C	27.8C	27.7	47.7C	20.0	47.9C	20.2								
13:15:00	29.1C	26.7C	27.9C	27.9	48.5C	20.6	48.6C	20.7								
13:30:00	29.2C	26.7C	27.9C	27.9	49.2C	21.3	49.4C	21.5								
13:45:00	28.9C	26.8C	28.0C	27.9	49.9C	22.0	50.1C	22.2								
14:00:00	28.8C	26.8C	28.1C	27.9	50.7C	22.8	50.8C	22.9								
14:15:00	28.9C	26.9C	28.1C	27.9	51.4C	23.5	51.5C	23.6								
14:30:00	29.1C	26.9C	28.2C	28.0	52.0C	24.0	52.1C	24.1								
14:45:00	28.8C	26.9C	28.2C	27.9	52.7C	24.8	52.8C	24.9								
15:00:00	29.0C	27.0C	28.3C	28.1	53.4C	25.3	53.5C	25.4								
15:15:00	29.2C	27.1C	28.4C	28.2	54.0C	25.8	54.1C	25.9								
18:15:00	28.5C	27.6C	28.9C	28.3	59.8C	31.5	59.7C	31.4								
21:15:00	28.5C	27.9C	29.3C	28.5	63.2C	34.7	62.9C	34.4								
00:15:00	28.7C	28.0C	29.5C	28.7	65.4C	36.7	65.1C	36.4								
03:15:00	28.7C	28.3C	29.7C	28.9	67.6C	38.7	67.3C	38.4								
06:15:00	28.5C	28.4C	29.8C	28.9	68.7C	39.8	68.4C	39.5								
07:23:05	28.0C	28.4C	29.9C	28.7	68.9C	40.2	68.6C	39.9								
09:08:39	27.9C	28.3C	29.9C	28.7	68.1C	39.4	67.8C	39.1								
09:14:15	27.7C	28.3C	29.9C	28.6	68.0C	39.4	67.8C	39.2								
09:15:00	27.7C	28.3C	29.9C	28.6	68.0C	39.4	67.7C	39.1								Shut down
09:53:08	25.7C	27.9C	29.5C	27.7	65.4C	37.7	65.3C	37.6								

1445 / 0830 / 6 15

B-22

WESTINGHOUSE FORM

TRANSFORMER TYPE: Pole TEMPERATURE TEST ON 25 K.V.A. TRANSFORMER STYLE Gen Elect.

CONNECTED H.V. 4160 VOLTS L.V. 120/240 VOLTS

LOAD H.V. 100% 6.0 AMPS. L.V. 104 AMPS. 60 CY.

WATTS PER LB. H.V. L.V. MAGNETIZED VOLTS CYCLES ON

GALLONS OIL CIRCUIT TEST METHOD Back NO. OF RADIATORS NO. TUBES

REMARKS * 1°C per minute used for Correction back to shut down

1 SERIAL # P239216-YOE

TIME AFTER SHUTDOWN MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORREC-TION TO SHDN.	AVE. WIND. TEMP.	TIME AFTER SHUTDOWN MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORREC-TION TO SHDN.
		25.0	5168	x.001	5.163		*				20.3	(.00520+.01)x1		.01520		
1	28		6428	"	6.423	86.01	1.5	87.51								*
									2	56		(.00910)+.01)x1		.01910	83.2	2.9

CALC. H.V. WINDING RISE $87.51 - 81 = 7.51°C$ DIFF / $87.51 - 27.3 = 60.21°C$ H.V. winding rise

CALC. L.V. WINDING RISE $86.13 - 81 = 6.13°C$ DIFF / $86.13 - 27.3 = 58.83°C$ L.V. winding rise

HOURS	TIME	TEMPERATURE READINGS TOP OIL	BTTM. OIL				AMB. OIL	TEMPERATURE RISE TOP OIL	BTTM. OIL				WATTMETER AND VOLTMETER
Steady State		81.0					27.3	53.7					

Meters across 2 transformers -100 %

A = 60

V = 60 x 4 (240)

W = 57.25 x 4 x 4 = 916

LOAD TEST AT ____ °C

AMPS

VOLTMETER

WATTMETER

NO LOAD TEST

(T.W.) WATTMETER

(A.W.) VOLTS ____ X AMPS ____ =

____ VA

TIME CONSTANT

63.3 x 53.7 °C OIL RISE = 34.0

TIME CONSTANT = 4 HRS. 30 MIN.

AL TYPE CONDUCTOR H.V.

AL TYPE CONDUCTOR L.V.

CALCULATED COMPROMISE CURRENT

OTHER REMARKS

front unit

H.V. resistance less .005 Ω for bridge lead resistance

TEST REQUESTED BY Greg Jones DATE TESTED 2-19-87 BY Bill Belvan L.SPEC. #

TRANSFORMER TYPE: Pole TEMPERATURE TEST ON 25 K.V.A. TRANSFORMER STYLE Gen. Electric

CONNECTED H.V. 4160 VOLTS L.V. 120/240 VOLTS

LOAD H.V. 100% 6.00 AMPS. L.V. 104 AMPS. 60 CYC

WATTS PER LB. H.V. ______ L.V. ______ MAGNETIZED ______ VOLTS ______ CYCLES ON ______

GALLONS OIL ______ CIRCUIT TEST METHOD Back NO. OF RADIATORS 0 NO. TUBES 0

REMARKS * 1°C per minute used for correction back to shutdown

SERIAL # P239217-Y0B

TIME AFTER SHUTDOWN MIN.	SEC.	TEMP. H.V. WINDING BY RESISTANCE AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.	AVE. WIND. TEMP.	TIME AFTER SHUTDOWN MIN.	SEC.	TEMP. L.V. WINDING BY RESISTANCE AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.
		25.0	5168	.001	5.163		*				20.3	(.00529+.01)x1				*
1	59		6405	"	6.400	94.90	2.0	86.9	3	27		(.00930+.01)x1		.01930	84.63	3.5

CALC. H.V. WINDING RISE $86.9-79.4=7.5°C$ DIFF / $86.9-27.3=59.6°C$ H.V. Winding Rise

CALC. L.V. WINDING RISE $88.1-79.4=8.7°C$ DIFF / $88.1-27.3°=60.8°C$ L.V. winding Rise

HOURS	TIME	TEMPERATURE READINGS TOP OIL	BTTM. OIL				AMB. OIL	TEMPERATURE RISE TOP OIL	BTTM. OIL				WATTMETER AND VOLTMETER	
Steady State		79.4					27.3	52.1						

LOAD TEST AT ______ °C

AMPS 6.00

VOLTMETER ______

WATTMETER ______

NO LOAD TEST

(T.W.) WATTMETER ______

(A.W.) VOLTS ______ X AMPS ______ = ______ VA

TIME CONSTANT

63.3 x 52.1 °C OIL RISE = 33.0

TIME CONSTANT = 4 HRS. 30 MIN.

AL TYPE CONDUCTOR H.V. size - ?

AL TYPE CONDUCTOR L.V. size - ?

CALCULATED COMPROMISE CURRENT NOT used

OTHER REMARKS

Rear Unit

TEST REQUESTED BY Greg Jones DATE TESTED 3-19-87 BY Bill Belvan L.SPEC. # ______

7 B. BELVAN ATHENS BACK/BACK 25KVA 4160V 240 GREG JONES 19 FEB 87 P239216 AND 17(REAR) 100 PCT

0050 700	01 AMB	02 AMB	03 AMB	04 AVER.	05 16 TOP	06 RISE	07 17 TOP	08 RISE	09	10	11	12	13	14	15	16
14:00:00	25.3C	24.2C	25.3C	24.9	25.5C	0.6	25.4C	0.5 — START UP								
14:15:00	25.3C	24.1C	25.3C	24.9	27.0C	2.1	26.9C	2.0								
14:30:00	25.3C	24.2C	25.3C	24.9	29.6C	4.7	29.5C	4.6								
14:45:00	25.3C	24.2C	25.4C	24.9	32.3C	7.4	32.0C	7.1								
15:00:00	25.3C	24.2C	25.4C	24.9	34.6C	9.7	34.3C	9.4								
15:15:00	25.4C	24.2C	25.5C	25.0	37.0C	12.0	36.5C	11.5								
15:30:00	25.4C	24.3C	25.5C	25.0	39.2C	14.2	38.7C	13.7								
15:45:00	25.5C	24.3C	25.6C	25.1	41.3C	16.2	40.7C	15.6								
16:00:00	25.5C	24.4C	25.6C	25.1	43.3C	18.2	42.6C	17.5								
16:15:00	25.5C	24.4C	25.6C	25.1	45.4C	20.3	44.6C	19.5								
16:30:00	25.6C	24.5C	25.7C	25.2	47.5C	22.3	46.6C	21.4								
16:45:00	25.6C	24.5C	25.8C	25.3	49.3C	24.0	48.4C	23.1								
17:00:00	25.7C	24.6C	25.8C	25.3	51.1C	25.8	50.1C	24.8								
17:15:00	25.7C	24.6C	25.8C	25.3	52.8C	27.5	51.8C	26.5								
17:30:00	25.7C	24.7C	25.9C	25.4	54.4C	29.0	53.3C	27.9								
17:45:00	25.8C	24.7C	25.9C	25.4	55.9C	30.5	54.8C	29.4								
18:00:00	25.8C	24.8C	26.0C	25.5	57.4C	31.9	56.1C	30.6								
18:15:00	25.9C	24.8C	26.0C	25.5	58.7C	33.2	57.4C	31.9								
18:30:00	25.9C	24.9C	26.1C	25.6	60.0C	34.4	58.6C	33.0	1830 1400 430							
18:45:00	26.0C	25.0C	26.2C	25.7	61.2C	35.5	59.7C	34.0								
19:00:00	26.0C	25.0C	26.2C	25.7	62.2C	36.5	60.7C	35.0								
19:15:00	26.1C	25.1C	26.2C	25.8	63.3C	37.5	61.8C	36.0								
19:30:00	26.1C	25.1C	26.3C	25.8	64.3C	38.5	62.8C	37.0								
19:45:00	26.2C	25.1C	26.3C	25.8	65.3C	39.5	63.7C	37.9								
20:00:00	26.2C	25.2C	26.4C	25.9	66.2C	40.3	64.6C	38.7								
20:15:00	26.2C	25.2C	26.4C	25.9	67.0C	41.1	65.4C	39.5								
20:30:00	26.3C	25.3C	26.5C	26.0	67.8C	41.8	66.1C	40.1								
20:45:00	26.4C	25.3C	26.5C	26.0	68.6C	42.6	67.0C	41.0								
21:00:00	26.4C	25.4C	26.6C	26.1	69.3C	43.2	67.6C	41.5								
21:15:00	26.4C	25.4C	26.6C	26.1	70.0C	43.9	68.3C	42.2								
21:30:00	26.5C	25.4C	26.7C	26.2	70.6C	44.4	68.9C	42.7								
21:45:00	26.5C	25.5C	26.7C	26.2	71.2C	45.0	69.5C	43.3								
22:00:00	26.5C	25.5C	26.7C	26.2	71.9C	45.7	70.1C	43.9								
22:15:00	26.6C	25.5C	26.8C	26.3	72.4C	46.1	70.6C	44.3								
22:30:00	26.6C	25.6C	26.8C	26.3	72.8C	46.5	71.1C	44.8								
22:45:00	26.7C	25.6C	26.9C	26.4	73.3C	46.9	71.5C	45.1								
23:00:00	26.7C	25.6C	26.9C	26.4	73.7C	47.3	71.9C	45.5								
23:15:00	26.7C	25.7C	26.9C	26.4	74.1C	47.7	72.3C	45.9								
23:30:00	26.7C	25.7C	27.0C	26.4	74.5C	48.1	72.7C	46.3								
23:45:00	26.8C	25.7C	27.0C	26.5	75.0C	48.5	73.3C	46.8								
00:00:00	26.8C	25.7C	27.0C	26.5	75.5C	49.0	73.7C	47.2								
00:15:00	26.9C	25.8C	27.0C	26.5	76.0C	49.5	74.2C	47.7								
00:30:00	26.9C	25.8C	27.1C	26.6	76.4C	49.8	74.7C	48.1								
00:45:00	26.9C	25.8C	27.1C	26.6	76.9C	50.2	75.1C	48.5								
01:00:00	27.0C	25.9C	27.2C	26.7	77.3C	50.6	75.6C	48.9								

7 B. BELVAN ATHENS BACK/BACK 25KVA 4160V 240 GREG JONES 19 FEB 87 P239216 AND 17(REAR) 100 PCT

0051 700	01 AMB	02 AMB	03 AMB	04 AVER.	05 16 TOP	06 RISE	07 17 TOP	08 RISE	09	10	11	12	13	14	15	16
01:15:00	27.0C	25.9C	27.2C	26.7	77.7C	51.0	75.9C	49.2								
01:30:00	27.0C	25.9C	27.2C	26.7	78.0C	51.3	76.3C	49.6								
01:45:00	27.1C	26.0C	27.3C	26.8	78.4C	51.6	76.7C	49.9								
02:00:00	27.1C	26.0C	27.3C	26.8	78.7C	51.9	77.0C	50.2								
02:15:00	27.1C	26.0C	27.3C	26.8	79.0C	52.2	77.3C	50.5								
02:30:00	27.2C	26.0C	27.4C	26.8	79.4C	52.6	77.6C	50.8								
02:45:00	27.2C	26.1C	27.4C	26.9	79.6C	52.7	77.8C	50.9								
03:00:00	27.2C	26.1C	27.4C	26.9	79.8C	52.9	78.1C	51.2								
03:15:00	27.2C	26.1C	27.4C	26.9	80.1C	53.2	78.4C	51.5								
03:30:00	27.3C	26.1C	27.5C	26.9	80.3C	53.4	78.6C	51.7								
03:45:00	27.3C	26.2C	27.5C	27.0	80.6C	53.6	78.8C	51.8								
04:00:00	27.3C	26.2C	27.5C	27.0	80.7C	53.7	78.9C	51.9								
04:15:00	27.3C	26.2C	27.5C	27.0	80.9C	53.9	79.1C	52.1								
04:30:00	27.3C	26.2C	27.6C	27.0	81.1C	54.1	79.3C	52.3								
04:45:00	27.4C	26.2C	27.6C	27.0	81.2C	54.2	79.4C	52.4								
05:00:00	27.4C	26.3C	27.6C	27.1	81.3C	54.2	79.5C	52.4								
05:15:00	27.4C	26.3C	27.6C	27.1	81.4C	54.3	79.6C	52.5								
05:30:00	27.4C	26.3C	27.6C	27.1	81.5C	54.4	79.7C	52.6								
05:45:00	27.4C	26.3C	27.7C	27.1	81.7C	54.6	79.9C	52.8								
06:00:00	27.5C	26.3C	27.7C	27.1	81.7C	54.6	79.9C	52.8								
06:15:00	27.5C	26.3C	27.7C	27.1	81.8C	54.7	80.1C	53.0								
06:30:00	27.5C	26.3C	27.7C	27.1	81.9C	54.8	80.2C	53.1								
06:45:00	27.5C	26.4C	27.7C	27.2	82.0C	54.8	80.2C	53.0								
07:00:00	27.5C	26.4C	27.8C	27.2	82.1C	54.9	80.3C	53.1								
07:15:00	27.5C	26.4C	27.7C	27.2	82.1C	54.9	80.3C	53.1								
07:16:00	27.5C	26.4C	27.7C	27.2	82.1C	54.9	80.4C	53.2								
08:16:00	27.6C	26.4C	27.8C	27.2	81.7C	54.5	79.9C	52.7								
09:16:00	27.6C	26.4C	27.7C	27.2	80.8C	53.6	79.1C	51.9								
10:16:00	27.6C	26.3C	27.7C	27.2	80.5C	53.3	78.8C	51.6								
11:16:00	27.6C	26.4C	27.7C	27.2	80.5C	53.3	78.8C	51.6								
12:16:00	27.6C	26.4C	27.7C	27.2	80.8C	53.6	79.1C	51.9								
13:16:00	27.7C	26.4C	27.8C	27.3	80.9C	53.6	79.2C	51.9								
13:39:58	27.7C	26.4C	27.8C	27.3	81.0C	53.7	79.4C	52.1	Shut down							

TEMPERATURE TEST RECORD
WESTINGHOUSE FORM 4857K

DTD LAB PAGE № 00727

TRANSFORMER TYPE: Pole TEMPERATURE TEST ON 25 KVA TRANSFORMER STYLE Gen Electric
CONNECTED H.V. 4160 (taps) VOLTS L.V. 120/240 VOLTS
LOAD H.V. 170% 10.2 AMPS. L.V. 176.8 AMPS. 60 CYCLES
WATTS PER LB. H.V. 21.9 L.V. 16.7 MAGNETIZED ___ VOLTS ___ CYCLES ON ___ V
GALLONS OIL ___ CIRCUIT TEST METHOD Back NO. OF RADIATORS ___ NO. TUBES ___
REMARKS ___
SERIAL # P217661 ACT

TIME AFTER SHUTDOWN MIN.	SEC.	TEMP. H.V. WINDING BY RESISTANCE: AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.	AVE. WIND. TEMP.	TIME AFTER SHUTDOWN MIN.	SEC.	TEMP. L.V. WINDING BY RESISTANCE: AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.
		25.5	3750	X.001	3.745						25.5	(.01+.00050)x1		.01050		
2	25		5640	"	5.635	151.9	3.3	155.2	3	45		(.01+.00555)x1		.01555	146.0	3.32

CALC. H.V. WINDING RISE: 155.2 − 127.7 = 27.5° DIFF / 155.2 − 26 = 129.2° winding rise

CALC. L.V. WINDING RISE: 149.4 − 127.7 = 21.67 DIFF / 149.4 − 26 = 123.4° winding rise

HOURS	TIME	TEMPERATURE READINGS: TOP OIL	BTTM. OIL			AMB. OIL	TEMPERATURE RISE: TOP OIL	BTTM. OIL	WATTMETER AND VOLTMETER
Steady State		127.7				26.0	101.7		

LOAD TEST AT ___ °C
AMPS ___
VOLTMETER ___
WATTMETER ___

NO LOAD TEST
(T.W.) WATTMETER ___
(A.W.) VOLTS ___ X AMPS ___ =
___ VA

TIME CONSTANT
63.3 X ___ °C OIL RISE = ___
TIME CONSTANT = 5 HRS. 15 MIN.

Al TYPE CONDUCTOR H.V.
Al TYPE CONDUCTOR L.V.

CALCULATED COMPROMISE CURRENT ___

OTHER REMARKS
new unit
watts per lb used at 170%:
$(1.7)^2$ x watts per lb used a
100% load

TEST REQUESTED BY Greg Jones DATE TESTED 2-5-87 BY Bill Belvan L.SPEC. #

TEMPERATURE TEST RECORD
WESTINGHOUSE FORM 4857K

DTD LAB PAGE № 00728

TRANSFORMER TYPE: Pole TEMPERATURE TEST ON 25 K.V.A. TRANSFORMER STYLE Gen Electric
CONNECTED H.V. 4160 Tap 5 VOLTS L.V. 120/240 VOLTS
LOAD H.V. 170% 10.2 AMPS. L.V. AMPS. CYCLES
WATTS PER LB. H.V. L.V. MAGNETIZED VOLTS CYCLES ON V
GALLONS OIL CIRCUIT TEST METHOD Back NO. OF RADIATORS NO. TUBES
REMARKS Amorphous Core SERIAL # ACT P217060

TIME AFTER SHUTDOWN MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES	CORREC-TION TO SHDN.	AVE. WIND. TEMP.	TIME AFTER SHUTDOWN MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORREC-TION TO SHDN.
		25.5	3740	.001	3.735						25.5	(.01+.00085)x1		.01085		
1	50		5616	"	5.605	150.9	2.6	153.5	3	10		(.01+.00605)x1		.01605	145.5	2.9

CALC. H.V. WINDING RISE $153.5-127.7=20.75°C$ DIFF / $153.5-26=127.5°$ H.V. Winding Rise

CALC. L.V. WINDING RISE $148.4-127.7=20.7°C$ DIFF / $148.4-26=122.4°C$ L.V. Winding Rise

HOURS	TIME	TEMPERATURE READINGS TOP OIL	BTTM. OIL		AMB. OIL	TEMPERATURE RISE TOP OIL	BTTM. OIL		WATTMETER AND VOLTMETER
Steady State									
170%	127.7				26.0	101.7			

LOAD TEST AT °C
AMPS
VOLTMETER
WATTMETER

NO LOAD TEST
(T.W.) WATTMETER
(A.W.) VOLTS X AMPS
VA

TIME CONSTANT at 170%
63.3 x 101.7 °C OIL RISE = 64.4
TIME CONSTANT 5 HRS. 15 MIN

Meters (across 2 transformers)

	Ammeter	Wattmeter	Voltmeter
[illegible]	2.55x4 (10.2)	149x4x4 (2384)	97.5x4 (390)

Al TYPE CONDUCTOR H.V. nameplate
Al TYPE CONDUCTOR L.V. nameplate
CALCULATED COMPROMISE CURRENT Not used
OTHER REMARKS

TEST REQUESTED BY Greg Jones DATE TESTED 2-5-87 BY Bill Belvan L SPEC #

7 B. BELVAN ATHENS BACK/BACK AMOR. CORES 25KVA 4160V 240 GREG JONES 09 FEB 87 P217061 AND 60(REAR) 170

09 10 11 12 13 14 15 16

0040 700	01 AMB	02 AMB	03 AMB	04 AVER.	05 61 TOP	06 RISE	07 60 TOP	08 RISE
09:05:00	21.7C	24.3C	25.8C	23.9	25.7C	1.8	25.8C	1.9
09:20:00	21.7C	24.4C	25.9C	24.0	27.3C	3.3	27.6C	3.6
09:35:00	21.9C	24.4C	25.8C	24.0	30.9C	6.9	31.3C	7.3
09:50:00	22.1C	24.4C	25.8C	24.1	35.2C	11.1	35.8C	11.7
10:05:00	22.2C	24.4C	25.8C	24.1	39.6C	15.5	40.3C	16.2
10:20:00	22.5C	24.4C	25.9C	24.2	43.9C	19.7	44.5C	20.3
10:35:00	22.4C	24.5C	25.9C	24.2	47.8C	23.6	48.5C	24.3
10:50:00	22.6C	24.5C	25.9C	24.3	51.6C	27.3	52.2C	27.[illegible]
11:05:00	22.5C	24.5C	26.0C	24.3	55.3C	31.0	55.9C	31.6
11:20:00	22.6C	24.5C	26.0C	24.3	58.8C	34.5	59.4C	35.1
11:35:00	22.6C	24.6C	26.0C	24.4	62.3C	37.9	62.9C	38.5
11:50:00	22.4C	24.6C	26.1C	24.3	65.6C	41.3	66.2C	41.9
12:05:00	22.7C	24.6C	26.1C	24.4	68.7C	44.3	69.2C	44.8
12:20:00	22.5C	24.7C	26.1C	24.4	71.5C	47.1	72.0C	47.6
12:35:00	22.6C	24.7C	26.2C	24.5	74.2C	49.7	74.6C	50.1
12:50:00	22.8C	24.8C	26.3C	24.6	76.7C	52.1	77.1C	52.5
13:05:00	22.6C	24.8C	26.3C	24.5	79.0C	54.5	79.5C	55.0
13:20:00	22.2C	24.9C	26.4C	24.5	81.2C	56.7	81.8C	57.3
13:35:00	22.7C	24.9C	26.4C	24.6	83.2C	58.6	83.8C	59.2
13:50:00	22.8C	25.0C	26.4C	24.7	85.2C	60.5	85.6C	60.9
~~14~~:05:00	22.9C	25.0C	26.5C	24.8	87.2C	62.4	87.5C	62.7
14:20:00	23.3C	25.1C	26.5C	24.9	88.9C	64.0	89.2C	64.3
14:35:00	23.5C	25.1C	26.6C	25.0	90.5C	65.5	90.8C	65.8
14:50:00	23.6C	25.2C	26.7C	25.1	91.8C	66.7	92.1C	67.0
15:05:00	23.8C	25.3C	26.8C	25.3	93.1C	67.8	93.3C	68.0
15:20:00	24.1C	25.3C	26.8C	25.4	94.2C	68.8	94.5C	69.1
15:35:00	24.1C	25.4C	26.9C	25.4	95.6C	70.2	95.8C	70.4
15:50:00	24.3C	25.4C	27.0C	25.5	97.2C	71.7	97.4C	71.9
16:05:00	24.3C	25.5C	27.1C	25.6	98.7C	73.1	98.9C	73.3
17:05:00	25.3C	25.8C	27.5C	26.2	104.0C	77.8	104.3C	78.1
18:05:00	25.4C	26.1C	27.8C	26.4	108.2C	81.8	108.5C	82.1
19:05:00	25.4C	26.3C	28.1C	26.6	111.4C	84.8	111.7C	85.1
20:05:00	24.7C	26.5C	28.4C	26.5	114.5C	88.0	114.7C	88.2
21:05:00	24.7C	26.7C	28.6C	26.6	116.5C	89.9	116.5C	89.9
22:05:00	24.1C	26.9C	28.8C	26.6	118.1C	91.5	118.2C	91.6
23:05:00	24.0C	27.0C	28.9C	26.6	119.3C	92.7	119.4C	92.8
00:05:00	23.8C	27.2C	29.0C	26.6	121.0C	94.4	121.1C	94.5
01:05:00	23.5C	27.3C	29.1C	26.6	122.8C	96.2	122.9C	96.3
02:05:00	23.0C	27.4C	29.2C	26.5	124.0C	97.5	124.1C	97.6
03:05:00	22.8C	27.4C	29.3C	26.5	125.1C	98.6	125.2C	98.7
04:05:00	22.7C	27.5C	29.3C	26.5	126.0C	99.5	126.1C	99.6
05:05:00	22.2C	27.5C	29.3C	26.3	126.6C	100.3	126.7C	100.4
06:05:00	22.0C	27.4C	29.3C	26.2	126.8C	100.6	127.0C	100.8
07:05:00	21.6C	27.4C	29.3C	26.1	127.1C	101.0	127.3C	101.2
08:05:00	21.6C	27.3C	29.2C	26.0	127.3C	101.3	127.5C	101.5

14:20 9:05

14:33 9:06

7 B. BELVAN ATHENS BACK/BACK AMOR. CORES 25KVA 4160V 240 GREG JONES 09 FEB 87 P217061 AND 60(REAR) 170-[illegible]

0041	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
700	AMB	AMB	AMB	AVER.	61 TOP	RISE	60 TOP	RISE								
09:05:00	21.3C	27.3C	29.1C	25.9	126.8C	100.9	127.1C	101.2								
10:05:00	21.6C	27.2C	29.2C	26.0	126.7C	100.7	126.9C	100.9								
11:05:00	21.2C	27.3C	29.2C	25.9	126.4C	100.5	126.6C	100.7								
12:05:00	22.4C	27.2C	29.3C	26.3	127.0C	100.7	127.1C	100.8								
12:59:13	21.8C	27.4C	29.4C	26.2	127.5C	101.3	127.5C	101.3								
13:05:00	21.5C	27.3C	29.4C	26.0	127.5C	101.5	127.6C	101.6								
13:19:28	21.7C	27.2C	29.3C	26.0	127.7C	101.7	127.7C	101.7	— shutdown							

TRANSFORMER TYPE: Pole TEMPERATURE TEST ON 25 K.V.A. TRANSFORMER STYLE Gen. Electric

CONNECTED H.V. 4160 VOLTS L.V. 120/240 VOLTS

LOAD H.V. 150% 9.0 AMPS. L.V. 156 AMPS. 60 CYC

WATTS PER LB. H.V. ? L.V. ? MAGNETIZED VOLTS CYCLES ON

GALLONS OIL CIRCUIT TEST METHOD Back NO. OF RADIATORS 0 NO. TUBES 0

REMARKS 150% Cooling curve used for resistance at time of shutdown

SERIAL # F239216-Y03

TIME AFTER SHUTDOWN MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.	AVE. WIND. TEMP.
		25.0			5.163			
2	01		7595	x.001	7.590	142.5		
		Cooling curve used →			7.730	149.3	—	149.3

TEMP. H.V. WINDING BY RESISTANCE

TIME AFTER SHUTDOWN MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.
		20.3	(.01+.00520)x1		.01520		
3	16		(.02+.00235)x1		.02235	135.7	
					.02269	141.17	—

TEMP. L.V. WINDING BY RESISTANCE

CALC. H.V. WINDING RISE $149.3 - 130.8 = 18.5°C$ DIFF. / $149.3 - 28.7 = 120.6°C$ winding rise H.V.

CALC. L.V. WINDING RISE $141.17 - 130.8 = 10.37°C$ DIFF / $141.17 - 28.7 = 112.4$[illegible] L.V. winding rise

HOURS	TIME	TEMPERATURE READINGS TOP OIL	BTTM. OIL				AMB. OIL	TEMPERATURE RISE TOP OIL	BTTM. OIL				WATTMETER AND VOLTMETER
Steady State		130.8					28.7	102.1					

Meters across 2 transformers 150%

Ammeter	Wattmeter	Voltmeter
90 amps	2400	388

LOAD TEST AT ____ °C

AMPS ____

VOLTMETER ____

WATTMETER ____

NO LOAD TEST

(T.W.) WATTMETER ____

(A.W.) VOLTS ____ X AMPS ____ =

____ VA

TIME CONSTANT

63.3 X ____ °C OIL RISE = ____

TIME CONSTANT = ____ HRS. ____ MIN.

Al TYPE CONDUCTOR H.V.

Al TYPE CONDUCTOR L.V.

CALCULATED COMPROMISE CURRENT ____

OTHER REMARKS

TEST REQUESTED BY Greg Jones DATE TESTED 2-23-87 BY Bill Belvan L.SPEC. #

TRANSFORMER TYPE: Pole TEMPERATURE TEST ON 25 K.V.A. ______ TRANSFORMER STYLE Gen. Electric

CONNECTED H.V. 4160 VOLTS L.V. 120/240 VOLTS

LOAD H.V. 150% 9.0 AMPS. L.V. 156 AMPS. 60 CYC

WATTS PER LB. H.V. ______ L.V. ______ MAGNETIZED ______ VOLTS ______ CYCLES ON ______

GALLONS OIL ______ CIRCUIT TEST METHOD Back ______ NO. OF RADIATORS ______ NO. TUBES ______

REMARKS 150% cooling curve used for resistance at time of shutdown

SERIAL # P239217-YOB

TIME AFTER SHUTDOWN MIN.	SEC.	TEMP. H.V. WINDING BY RESISTANCE AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.	AVE. WIND. TEMP.	TIME AFTER SHUTDOWN MIN.	SEC.	TEMP L.V. WINDING BY RESISTANCE AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.
		25			5.163		for reference				203	(.00529	+.01)x1	.01529		
1	31		7595	x.001	7.59	142.5			2	40		(.00235	+.02)x1	.02235	133.6	13
	resist by		Cooling curve →		7.692	147.5	–	147.5	resistance			Cooling	curve →	.02268	→	138.9

CALC. H.V. WINDING RISE $147.5 - 128.5 = 19.0°C$ DIFF. / $147.5 - 28.7 = 118.8°C$ Winding rise

CALC. L.V. WINDING RISE $138.9 - 128.5 = 10.4°C$ diff / $138.9 - 28.7 = 110.2$ Winding rise

HOURS	TIME	TEMPERATURE READINGS TOP OIL	BTTM. OIL				AMB. OIL	TEMPERATURE RISE TOP OIL	BTTM. OIL				WATTMETER AND VOLTMETER	
Steady State		128.5					28.7	99.8						

LOAD TEST AT ______ °C

AMPS ______

VOLTMETER ______

WATTMETER ______

NO LOAD TEST

(T.W.) WATTMETER ______

(A.W.) VOLTS ______ X AMPS ______ =

______ VA

TIME CONSTANT

63.3 X ______ °C OIL RISE = ______

TIME CONSTANT = ______ HRS. ______ MIN.

TYPE CONDUCTOR H.V. ______

TYPE CONDUCTOR L.V. ______

CALCULATED COMPROMISE CURRENT ______

OTHER REMARKS

TEST REQUESTED BY Greg Jones DATE TESTED 3-23-87 BY Bill Belvan L.SPEC. # ______

7 B. BELVAN ATHENS BACK/BACK 25KVA 4160V 240 GREG JONES 23 FEB 87 P239216 AND 17(REAR) 170 PCT

0054 700	01 AMB	02 AMB	03 AMB	04 AVER.	05 16 TOP	06 RISE	07 17 TOP	08 RISE	09	10	11	12	13	14	15	16
08:06:00	26.0C	24.8C	26.0C	25.6	26.0C	0.4	25.9C	0.3								
08:21:00	26.0C	24.7C	25.9C	25.5	32.1C	6.6	32.6C	7.1								
08:36:00	25.9C	24.7C	25.9C	25.5	39.7C	14.2	39.7C	14.2								
08:51:00	26.0C	24.7C	26.0C	25.5	46.6C	21.1	46.4C	20.9								
09:06:00	26.0C	24.7C	26.0C	25.5	53.0C	27.5	52.4C	26.9								
09:21:00	25.9C	24.7C	26.0C	25.5	59.0C	33.5	58.1C	32.6								
09:36:00	26.0C	24.7C	26.0C	25.5	64.4C	38.9	63.5C	38.0								
09:51:00	26.0C	24.8C	26.1C	25.6	69.4C	43.8	68.1C	42.5								
10:06:00	26.0C	24.8C	26.1C	25.6	74.3C	48.7	72.6C	47.0								
10:21:00	26.0C	24.9C	26.2C	25.7	79.6C	53.9	77.6C	51.9								
10:36:00	26.1C	24.9C	26.2C	25.7	84.3C	58.6	82.2C	56.5								
10:51:00	26.1C	24.9C	26.2C	25.7	88.9C	63.2	86.6C	60.9								
11:06:00	26.1C	25.0C	26.3C	25.8	93.2C	67.4	90.8C	65.0								
11:21:00	26.2C	25.0C	26.3C	25.8	97.5C	71.7	95.0C	69.2								
11:36:00	26.2C	25.1C	26.4C	25.9	101.7C	75.8	99.1C	73.2								
11:51:00	26.3C	25.1C	26.5C	25.9	105.6C	79.7	102.8C	76.9								
12:06:00	26.3C	25.2C	26.5C	26.0	108.9C	82.9	106.0C	80.0								
12:21:00	26.4C	25.2C	26.6C	26.0	112.1C	86.1	109.1C	83.1								
12:36:00	26.4C	25.3C	26.7C	26.1	114.9C	88.8	111.8C	85.7								
12:51:00	26.5C	25.4C	26.8C	26.2	117.4C	91.2	114.3C	88.1								
13:06:00	26.6C	25.4C	26.8C	26.2	119.7C	93.5	116.5C	90.3								
13:21:00	26.7C	25.5C	26.9C	26.3	121.9C	95.6	118.7C	92.4								
13:26:00	26.7C	25.6C	27.0C	26.4	122.7C	96.3	119.3C	92.9								
13:41:00	26.7C	25.6C	27.0C	26.4	123.3C	96.9	120.0C	93.6								
13:56:00	26.8C	25.7C	27.1C	26.5	123.5C	97.0	120.3C	93.8								
14:11:00	26.8C	25.8C	27.2C	26.6	123.8C	97.2	120.7C	94.1								
14:26:00	26.9C	25.9C	27.2C	26.6	124.1C	97.5	121.0C	94.4								
14:41:00	26.9C	25.9C	27.3C	26.7	124.5C	97.8	121.3C	94.6								
14:56:00	27.0C	26.0C	27.4C	26.8	124.9C	98.1	121.8C	95.0								
15:11:00	27.1C	26.1C	27.5C	26.9	125.4C	98.5	122.2C	95.3								
15:26:00	27.2C	26.1C	27.5C	26.9	125.8C	98.9	122.7C	95.8								
15:41:00	[illegible]	26.2C	27.6C	27.0	126.3C	99.3	123.2C	96.2								
15:56:00	27.3C	26.3C	27.7C	27.1	126.7C	99.6	123.6C	96.5								
16:11:00	27.4C	26.3C	27.8C	27.1	127.1C	100.0	124.0C	96.9								
16:26:00	27.4C	26.4C	27.9C	27.2	127.4C	100.2	124.3C	97.1								
16:41:00	27.5C	26.4C	27.9C	27.2	127.6C	100.4	124.6C	97.4								
16:56:00	27.5C	26.5C	28.0C	27.3	127.8C	100.5	124.8C	97.5								
17:11:00	27.6C	26.5C	28.0C	27.3	128.0C	100.7	125.1C	97.8								
17:26:00	27.7C	26.5C	28.1C	27.4	128.2C	100.8	125.3C	97.9								
17:41:00	27.7C	26.6C	28.1C	27.4	128.5C	101.1	125.6C	98.2								
[illegible]56:00	27.7C	26.6C	28.2C	27.5	128.7C	101.2	125.8C	98.3								
[illegible]11:00	27.8C	26.7C	28.2C	27.5	128.9C	101.4	126.1C	98.6								
18:26:00	27.8C	26.7C	28.3C	27.6	129.0C	101.4	126.2C	98.6								
18:41:00	27.9C	26.7C	28.3C	27.6	129.0C	101.4	126.3C	98.7								
18:56:00	27.9C	26.8C	28.3C	27.5	129.0C	101.4	126.3C	98.7								

drop to 150% loading

2°

1.4°

Meters cross 2 transformers 150%

Voltmeter 3

Voltmeter 240

Ammeter 40 amps

7 B. BELVAN ATHENS BACK-BACK 25KVA 4160V 240 GREG JONES 23 FEB 87 P239216 AND 17(REAR) 15D 17A-

0054 700	01 AMB	02 AMB	03 AMB	04 AVER.	05 15 TOP	06 RISE	07 17 TOP	08 RISE	09	10	11	12	13	14	15	16
19:11:00	27.90	26.90	28.30	27.6	128.90	101.3	126.30	98.7								
19:26:00	27.90	26.80	28.30	27.6	128.90	101.3	126.30	98.7								
19:41:00	28.00	26.80	28.40	27.7	129.10	101.4	126.50	98.8								
19:56:00	28.00	26.90	28.40	27.7	129.20	101.5	126.60	98.9								
20:11:00	28.00	26.90	28.40	27.7	129.20	101.5	126.70	99.0								
20:26:00	28.10	26.90	28.50	27.8	129.10	101.3	126.70	98.9								
20:41:00	28.10	27.00	28.50	27.8	129.20	101.4	126.70	98.9								
20:56:00	28.20	27.00	28.60	27.9	129.20	101.3	126.70	98.8								
21:11:00	28.20	27.00	28.60	27.9	129.20	101.3	126.80	98.9								
21:26:00	28.30	27.10	28.70	28.0	129.30	101.3	126.90	98.9								
21:41:00	28.40	27.20	28.80	28.1	129.40	101.3	127.00	98.9								
21:56:00	28.40	27.20	28.80	28.1	129.50	101.4	127.20	99.1								
22:11:00	28.50	27.20	28.80	28.1	129.70	101.6	127.30	99.2								
22:26:00	28.50	27.30	28.90	28.2	129.80	101.6	127.50	99.3								
22:41:00	28.60	27.30	28.90	28.2	130.00	101.8	127.70	99.5								
22:56:00	28.60	27.30	28.90	28.2	130.20	102.0	128.00	99.6								
23:11:00	28.60	27.30	29.00	28.3	130.40	102.1	128.10	99.8								
23:26:00	28.70	27.40	29.00	28.3	130.60	102.3	128.30	100.0								
23:41:00	28.70	27.40	29.10	28.4	130.90	102.5	128.80	100.4								
23:56:00	28.70	27.40	29.10	28.4	131.40	103.0	129.20	100.8								
00:11:00	28.80	27.50	29.10	28.4	131.70	103.3	129.60	101.2								
00:26:00	28.80	27.50	29.20	28.5	132.10	103.6	130.00	101.5								
00:41:00	28.90	27.60	29.20	28.5	132.50	104.0	130.40	101.9								
00:56:00	28.90	27.70	29.30	28.6	132.90	104.3	130.70	102.1								
01:11:00	28.90	27.60	29.30	28.6	133.20	104.6	131.10	102.5								
01:26:00	28.90	27.70	29.30	28.6	133.50	104.9	131.50	102.9								
01:41:00	29.00	27.70	29.40	28.7	133.80	105.1	131.80	103.1								
01:56:00	29.00	27.70	29.40	28.7	134.10	105.4	132.10	103.4								
02:11:00	29.00	27.70	29.40	28.7	134.30	105.6	132.30	103.6								
02:26:00	29.00	27.80	29.40	28.7	134.60	105.9	132.60	103.9								
02:41:00	29.10	27.80	29.50	28.8	134.90	106.1	132.90	104.1								
02:56:00	29.10	27.80	29.50	28.8	135.10	106.3	133.20	104.4								
03:11:00	29.10	27.80	29.50	28.8	135.30	106.5	133.40	104.6								
03:26:00	29.20	27.90	29.60	28.9	135.50	106.6	133.60	104.7								
03:41:00	29.20	27.90	29.50	28.8	135.70	106.9	133.80	105.0								
03:56:00	29.20	27.90	29.60	28.9	135.90	107.0	134.00	105.1								
04:11:00	29.20	27.90	29.60	28.9	136.10	107.2	134.20	105.3								
04:26:00	29.20	28.00	29.60	28.9	136.10	107.2	134.30	105.4								
04:41:00	29.20	27.90	29.60	28.9	136.30	107.4	134.40	105.5								
04:56:00	29.30	28.00	29.70	29.0	136.30	107.3	134.50	105.5								
05:11:00	29.30	28.00	29.70	29.0	136.40	107.4	134.50	105.5								
05:26:00	29.30	28.00	29.70	29.0	136.40	107.3	134.50	105.5								
05:41:00	29.30	28.00	29.70	29.0	136.30	107.3	134.50	105.5								
05:56:00	29.30	28.00	29.80	29.0	136.30	107.3	134.40	105.4								
06:11:00	29.30	28.00	29.80	29.0	136.10	107.1	134.30	105.3								

7 B. BELVAN ATHENS BACK/BACK 25KVA 4160V 240 GREG JONES 23 FEB 87 P239216 AND 17 REAR 150 ~~170~~ PCT

0055 TOD	01 AMB	02 AMB	03 AMB	04 AVER.	05 16 TOP	06 RISE	07 17 TOP	08 RISE	09	10	11	12	13	14	15	16
06:26:00	29.40	29.00	29.80	29.0	136.10	107.1	134.30	105.3								
06:41:00	29.40	28.10	29.80	29.1	136.10	107.0	134.20	105.1								
06:56:00	29.40	28.10	29.80	29.1	136.00	106.9	134.10	105.0								
07:11:00	29.40	28.10	29.80	29.1	135.90	106.8	134.00	104.9								
07:26:00	29.40	28.10	29.80	29.1	135.70	106.6	133.80	104.7								
07:41:00	29.40	28.10	29.80	29.1	135.30	106.2	133.30	104.2								
07:56:00	29.40	28.10	29.60	29.1	134.60	105.5	132.60	103.5 — adjust current from Hite hours								
08:11:00	29.40	28.00	29.70	29.0	133.60	104.6	131.60	102.6								
08:26:00	29.30	28.00	29.70	29.0	132.80	103.8	130.70	101.7								
08:41:00	29.40	28.00	29.70	29.0	133.10	104.1	130.90	101.9								
08:56:00	29.40	27.90	29.60	28.9	132.90	104.0	130.80	101.9								
09:11:00	29.30	27.90	29.60	28.9	132.70	103.8	130.60	101.7								
09:26:00	29.30	27.90	29.60	28.9	132.50	103.6	130.40	101.5								
09:41:00	29.30	27.90	29.60	28.9	132.30	103.4	130.30	101.4								
09:56:00	29.30	27.90	29.50	28.9	132.10	103.2	130.00	101.1								
10:11:00	29.30	27.90	29.50	28.9	132.00	103.1	129.80	100.9								
10:26:00	29.30	27.80	29.50	28.8	131.60	102.8	129.50	100.7								
10:36:00	29.30	27.80	29.50	28.8	131.40	102.6	129.30	100.5								
11:36:00	29.20	27.70	29.40	28.7	130.90	102.2	128.80	100.1								
12:36:00	29.10	27.70	29.40	28.7	130.80	102.1	128.60	99.9								
13:36:00	29.20	27.70	29.40	28.7	130.80	102.1	128.50	99.8 ~ Shutdown 150%								

7 B. BELVAN ATHENS BACK/BACK 25KVA 4160V 240 GREG JONES 23 FEB 87 P239216 AND 17 REAR 170 PCT

0055 TOD	01 AMB	02 AMB	03 AMB	04 AVER.	05 16 TOP	06 RISE	07 17 TOP	08 RISE	09	10	11	12	13	14	15	16

*** POWER OFF AT 0055:13:56:08, PC = 267E

WESTINGHOUSE DTD COMMERCIAL TEST REPORT — DATE: [illegible]

CONDITION: FOLLOWING 170% TEMPERATURE RISE

STYLE: G.E. 25KVA AMORPHOUS METAL POLE TYPE

LV: [illegible] HV: [illegible] 75KV BIL SERIAL #:[illegible]

RATIO	PASS	* HV RESISTANCE (OHMS)	[illegible]
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01364
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	[illegible]
APPLIED POTENTIAL - HLIO	PASS	*[illegible]	[illegible]
APPLIED POTENTIAL - LHIO	PASS	* LOAD LOSS (WATTS)	[illegible]
INDUCED POTENTIAL - [illegible]	PASS	TOTAL LOSS (WATTS)	[illegible]
NL LOSS (WATTS)	[illegible]	* % RESISTANCE	[illegible]
% EXCITING CURRENT	[illegible]	* % REACTANCE	[illegible]
% EFFICIENCY @ [illegible]	[illegible]	* % IMPEDANCE	[illegible]
% EFFICIENCY @ [illegible]	[illegible]	% REGULATION @ [illegible]	[illegible]
		% REGULATION @ [illegible]	[illegible]

Gregg V. Jones

WESTINGHOUSE DTG COMMERCIAL TEST REPORT

DATE: [illegible]

CONDITION: FOLLOWING 170% TEMPERATURE RISE

STYLE: G.E. 25kVA AMORPHOUS METAL POLE TYPE

LV: 120/240 HV: 4160 75kV BIL SERIAL #:P217061-YZA

RATIO	PASS	* HV RESISTANCE (OHMS)	4.73[illegible]
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01334
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	[illegible]15.[illegible]
APPLIED POTENTIAL - HLIC	PASS	* STRAYS	10.[illegible]
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	326.0
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	344.[illegible]
NL LOSS (WATTS)	18.3	* % RESISTANCE	1.30
% EXCITING CURRENT	[illegible].2	* % REACTANCE	[illegible]
% EFFICIENCY @ PF=1	[illegible]6.6	* % IMPEDANCE	[illegible].49
% EFFICIENCY @ PF=.8	99.3	% REGULATION @ PF=1	[illegible]
		% REGULATION @ PF=.8	[illegible]

TEST ENGINEER: Gregg V. Jones

GREGG V. JONES

* CORRECTED TO 85 DEGREES C

WESTINGHOUSE UTD COMMERCIAL TEST REPORT   DATE: [illegible]

CONDITION: FOLLOWING 150% TEMPERATURE RISE

STYLE: G.E. 25KVA STANDARD SILICON STEEL POLE TYPE

LV: 120/240   HV: 4160Y   75KV BIL   SERIAL #:P23F216-70B

RATIO	PASS	* HV RESISTANCE (OHMS)	6.5001
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.019358
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	444.8
APPLIED POTENTIAL - HLIC	PASS	* STRAYS	1.2
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	446.0
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	511.3
NL LOSS (WATTS)	65.7	* % RESISTANCE	1.78
% EXCITING CURRENT	0.9	* % REACTANCE	2.22
% EFFICIENCY @ PF=1	98.0	* % IMPEDANCE	2.85
% EFFICIENCY @ PF=.8	97.5	% REGULATION @ PF=1	1.81
		% REGULATION @ PF=.8	2.75

TEST ENGINEER: Gregg V. Jones
GREGG V. JONES

* CORRECTED TO 85 DEGREES C

WESTINGHOUSE DTD COMMERCIAL TEST REPORT DATE:[illegible]

CONDITION: FOLLOWING 150% TEMPERATURE RISE

STYLE: G.E. 25KVA STANDARD SILICON STEEL POLE TYPE

LV: [illegible] HV: [illegible] 75KV BIL SERIAL #:[illegible]

RATIO	PASS	* HV RESISTANCE (OHMS)	5.4984
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01927
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	443.8
APPLIED POTENTIAL - HLIC	PASS	*STRAYS	5.7
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	449.5
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	519.4
NL LOSS (WATTS)	69.9	* % RESISTANCE	1.80
% EXCITING CURRENT	0.87	* % REACTANCE	2.24
% EFFICIENCY @ PF=1	98.0	* % IMPEDANCE	2.87
% EFFICIENCY @ PF=.8	97.5	% REGULATION @ PF=1	1.80
		% REGULATION @ PF=.8	2.79

TEST ENGINEER: Gregg V Jones

GREGG V. JONES

* CORRECTED TO 85 DEGREES C

APPENDIX A.3

SOUND LEVEL TEST REPORTS

January 29, 1987

Roger Angelo Lucheta

Westinghouse Research Laboratory

1310 Beulah Road

Pittsburgh, PA 15235

Subject: Noise Test of Transformer

A report of the noise evaluation of a 25 kVA General Electric transformer, s/n P217059-YZA, is attached. The evaluation was performed by Dr. Francis McKendree at the Westinghouse Churchill Site during the period January 27, 1987 to January 29, 1987.

I have observed the performance of the tests and checked the calculations in the report. I certify that these noise measurements comply with the applicable provisions ANSI/IEEE Std. 141-1986, NEMA standard TR 1-1980, and ANSI/IEEE C57.12.90-1980.

Roger Angelo Lucheta

Roger Angelo Lucheta

SOUND MEASUREMENTS OF 25 kVA

GENERAL ELECTRIC TRANSFORMER

S/N P217059-YZA

Francis S. McKendree

Westinghouse R&D Center
1310 Beulah Road
Pittsburgh, PA 15235

DESCRIPTION OF TEST

Airborne sound pressure levels were measured in accordance with ANSI standard C57.12.90-1980 for sound measurement of transformers. The normal excitation was used, 120 V to each side of the secondary, and 10% above normal, 132 V to each side of the secondary. The room is a hemi-anechoic space located at the Westinghouse Churchill Site, Building 302, Room 102C. The measurements were made on 27 and 28 January 1987.

ANSI C57.12.90-1980 specifies that instrumentation for the sound level measurements shall meet the requirements of ANSI S1.4-1971 for Type 2 meters. The instrumentation used satisfies Type 1 requirements throughout. Type 1 compliance is inclusive of Type 2 compliance, since all requirements for Type 1 are more stringent than those for Type 2.

Airborne sound pressure levels were measured at one foot from the transformer case, beginning at the front center and spaced 90 degrees apart. The reported sound pressure levels are the averages over the test positions, for the indicated excitations. Narrow band sound pressure level spectra were also recorded at each test position and condition.

The transformer was serial number P217059-YZA of 25 kVA capacity. Because its noise levels were extraordinarily low, a second procedure in the standard ANSI C57.12.90-1980, regarding the use of narrow band spectral measurements, was also employed to give a better approximation of the actual sound pressure levels emitted by the transformer.

EQUIPMENT USED

The equipment used for these measurements is listed below:

Manufacturer	Model	Serial	Description/Notes
B&K	4220	1164904	pistonphone, 124.1 dB nominal, NBS traceable
B&K	4145	819114	microphone, 1 inch
B&K	2613	226513	mic preamp
B&K	2603	9A6253	measuring amplifier
Gen Rad	1925	181228	1/3 octave multifilter
DEC	11/24	AG02930	laboratory computer system with A/D

Roger Angelo Lucheta

One-third octave band spectra were measured at each test position for no excitation, 120 V, and 132 V excitation. The spectra were summed on a true power basis in accordance with the applicable standard. The A-weighted levels reported for the transformers were derived from the spectra. The spectra and derived, arithmetically-averaged A-weighted levels, are listed in Table 1.

TABLE 1

One-third Octave Bands and A-weighted Levels Measured
on Transformer P217059-YZA Under Various Excitations

BAND	AMBIENT	120 V	132 V
50	36.8	36.6	36.0
63	41.2	40.9	40.7
80	34.7	34.5	34.1
100	31.4	33.4	33.6
125	29.7	35.6	39.4
160	26.6	27.2	27.2
200	24.2	24.8	25.0
250	22.4	27.8	28.3
315	20.8	24.2	26.2
400	19.9	25.4	29.2
500	19.0	23.2	33.8
630	18.7	22.4	34.4
800	19.2	20.6	26.8
1000	18.6	19.8	23.8
1250	18.4	18.9	22.6
1600	18.6	19.1	20.8
2000	19.3	19.6	20.2
2500	19.7	20.1	20.4
3150	20.4	20.6	20.9
4000	20.8	21.3	21.9
5000	21.0	21.2	21.6
dB(A)	32.4	34.0	38.6

Roger
Angelo
Lucheta

ANSI standard C57.12.90-1980 specifies procedures which are to be used if the ambient level measured in a given band, or with a given weighting, are within 10 dB of the combined ambient and transformer sound levels. For the ambient between 5 and 10 dB below the combined level, a correction is allowed to produce a reportable sound level for the transformer. If the ambient is within 5 dB of the combined level, the level must be reported as a level which the tested unit "does not exceed".

The A-weighted ambient level was 32.6 dB before the tests and 32.3 dB after the tests, for an average of 32.4 dB. The average A-weighted level was 34.0 dB with 120 V excitation, and 38.6 dB with 132 V excitation to each side of the transformer secondary.

Since the ambient level is within 5 dB of the combined level with 120 V excitation, the A-weighed average is reduced by 1.6 dB, and the net level is reported as the level which the transformer does not exceed:

> "In accordance with ANSI C57.12.90-1980, the A-weighed sound level of transformer P217059-YZA, when excited with 120 V, does not exceed 32.4 dB(A)."

The average A-weighted sound pressure level when the transformer is driven with 132 V is between 5 and 10 dB above the ambient. Reference to the standard indicates a correction of 1.3 dB is appropriate, and the net level shall be reported as the sound level of the transformer:

> "In accordance with ANSI C57.12.90-1980 except with regard to the excitation voltage,, transformer P217059-YZA, when excited with 132 V to each side of the secondary, produces an average A-weighted sound level of 37.3 dB(A)."

Roger
Angelo
Luchetta

ANSI C57.12.90-1980 permits measurements of narrow band tonal components. As the ambient noise is relatively broad band, a better signal-to-noise ratio can be obtained with narrow band measurements. When the tone levels of a transformer are to be measured, the even harmonics of the line frequency are to be measured up to and including the seventh. For the unit under test, these are 120, 240, 360, 480, 500, 720, and 840 Hz. The tone levels are to be averaged over the specified positions on a true power basis. The tones may be A, C, or linearly weighted, and may be summed on a true power basis to give the average sound level for the chosen weighting.

In ANSI S1.4-1971, a "sound pressure level" is defined as "20 times the logarithm to the base 10 of the ratio of the pressure of a sound to the reference pressure", and a "sound level" is defined as "Weighted sound pressure level measured by the use of a metering characteristic and weighting A, B, or C as specified in this standard". The A-weighting, originally developed as an approximation to the Fletcher-Munson 40 phon curve and specified as a set of time constants for an electrical filter network, is in ANSI S1.4-1971 defined at discrete frequencies corresponding to the center frequencies of the preferred 1/3 octave bands from 10 to 20,000 Hz.

The author uses a quadratic interpolation between the entries of this table to derive an [illegible]ighting coefficient for a tonal noise at a frequency not equal to one of the preferred 1/3 octave band centers. The error which may be introduced by this procedure is far less than the tolerances which are permitted or a Class 1 implementation of the A-weighting network itself.

Narrow band spectra were measured on a 1 kHz frequency range with 400 lines of resolution, and the tone levels of the first seven harmonics of 120 Hz were measured. The tone levels are presented in Table 2.

TABLE 2

Tone Levels of Twice-line-frequency Harmonics

FREQUENCY	AMBIENT	120 V	132 V
120	23.6	35.7	39.9
240	12.4	27.7	29.2
360	6.4	24.8	31.0
480	2.6	21.3	34.3
600	2.0	17.6	31.0
720	1.7	13.9	25.4
840	2.2	6.3	20.6

Roger
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All of the tone levels, which were measured with an effective bandwidth of 3.2 Hz, were more than 10 dB above the ambient, except for 840 Hz with 120 V excitation. This level was originally 7.6 dB, which is 5.2 dB above the ambient. In accordance with the ANSI standard procedure, the measured level has been reduced 1.3 dB and is reported as 6.3 dB.

Copies of 1 kHz and 2 kHz bandwidth spectral plots, for ambient and energized conditions at the front center of the transformer, are included with this report. It is evident that the tone levels can be reliably measured, since they are clearly above the ambient levels.

Table 3 shows the results of applying the A weighting to the first seven harmonics of the double line frequency. The A weighting values shown are derived from a quadratic interpolation from the tabulated A-weighting response curve in ANSI S1.4-1971.

TABLE 3

A-weighting and A-weighted Tone Levels

Frequency	A-Weight		120 V	132 V
120	-16.6		19.1	23.3
240	- 9.0		18.7	20.2
360	- 5.6		19.2	25.4
480	- 3.5		17.8	30.8
600	- 2.2		15.4	28.8
720	- 1.3		12.6	24.1
840	- 0.6		5.7	20.0
		dB(A) sum	25.5	34.7

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Angelo
Lucheta

Examination of the 2 kHz spectral plots confirms that the first seven harmonics of twice the line frequency contain almost all of the sound energy, even after the A weighting is taken into account. The tone level and band levels may be compared as shown below in Table 4.

Roger Angelo Lucheta

TABLE 4

Comparison of Tone and Band Levels at Selected Frequencies

Condition	120 Hz Tone	125 Hz Band	240 Hz Tone	250 Hz Band
Ambient	23.6	29.7	12.4	22.4
120 Volt	35.7	35.6	27.7	27.8
132 Volt	39.9	39.4	29.2	28.3

The tone and band levels are quite comparable for the energized conditions, since in these bands the only significant component is the tone from the transformer. Under ambient conditions, the noise is relatively broad-band, so the tone level at a discrete frequency is considerably lower than the band level, which encompasses a range of frequencies.

The band levels above 840 Hz are dominated by the ambient noise, even with the transformer energized. The ANSI procedure for adjustment due to ambient noise is limited to 1.6 dB, which is inadequate to deal with noise levels as close to the ambient as those documented in this report. Section 13.5.4 reads:

> "13.5.4 If ambient conditions necessitate, the sound level may be measured using discrete frequency components (see 13.6.4.)"

The sum of the levels of the first seven harmonics is 25.5 dB(A) for the 120 V excitation, and 34.7 dB(A) for the 132 V excitation. It will be recalled that the ANSI standard method applied to the

A-weighted measurements gave a result of "not exceeding 32.4 dB(A)" for 120 V and of 37.3 dB(A) with 132 V excitation. It is the opinion of the author that the A-weighted results, though they have been corrected in accordance with the ANSI standard, still have resulted in an overestimate of the actual transformer levels.

> "In accordance with the Optional Frequency Analysis Procedure which described in section 13.6 of ANSI standard C57.12.90--1980, the sound level of transformer P217059-YZA on the A-weighting scale is 25.5 dB(A) at 120 Volts excitation to each side of the secondary, and 34.7 dB(A) with 132 Volts excitation to each side of the secondary."

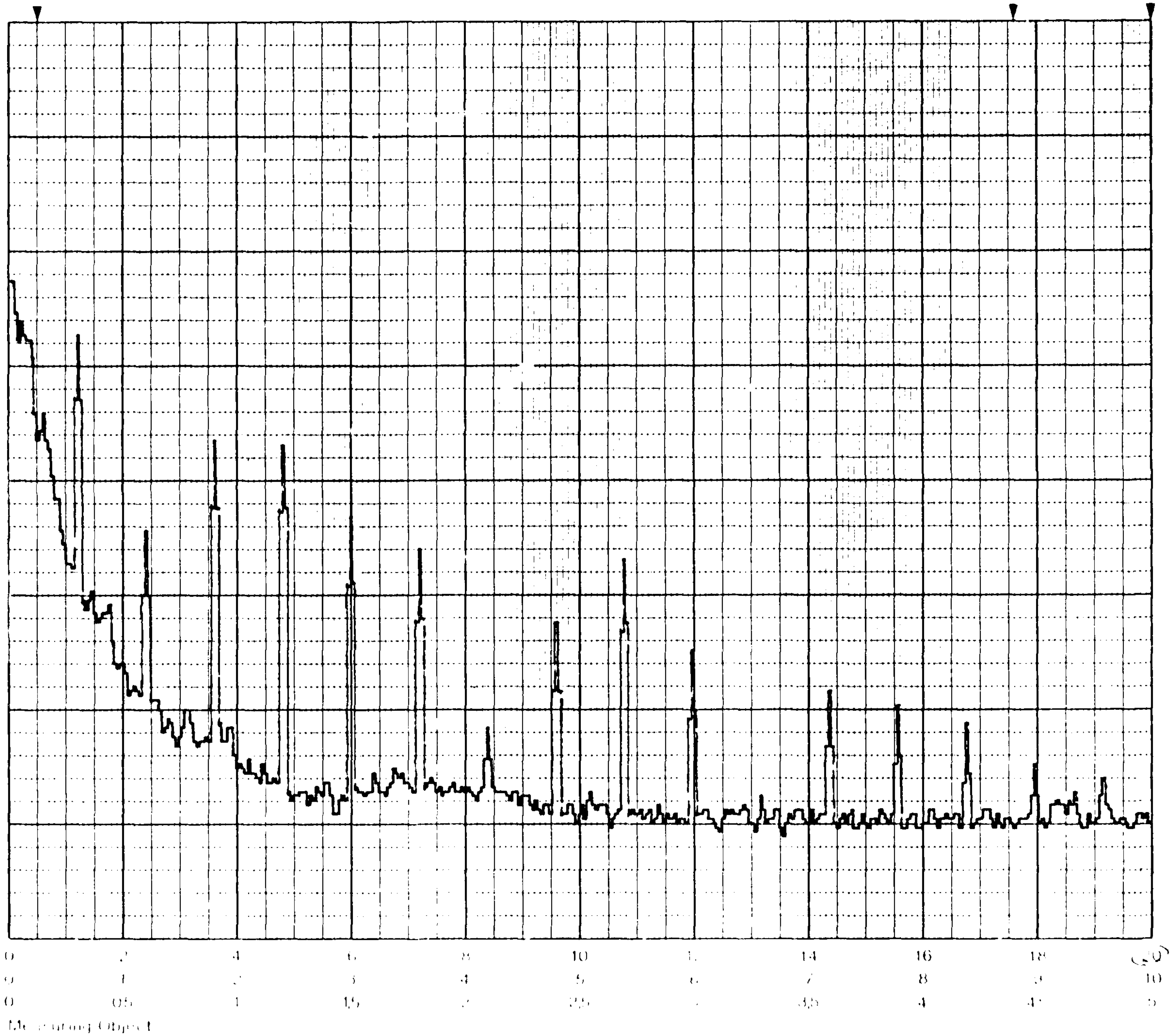
Roger Angelo Lucheta

Bruel & Kjær | Time Function Start | seconds | End | seconds | Not Expanded | Expanded

Full Scale Level 70
F. S. Frequency 2K Hz
Weighting Hann
Average Mode Lin
No of Spectra 64

Comments
132v Left-Center
Position 1

25KVA-GE
SN PD17059-YZA



B-53

Roger Angelo Sucheta

Record No
Date 1-28-87
Sign J. Uber

QP 1002

Bruel & Kjær

Full Scale Level 70
F S Frequency 2KHz
Weighting Hann
Average Mode Lin
No of Spectra 64

Comments
120v Left Center
Position 1

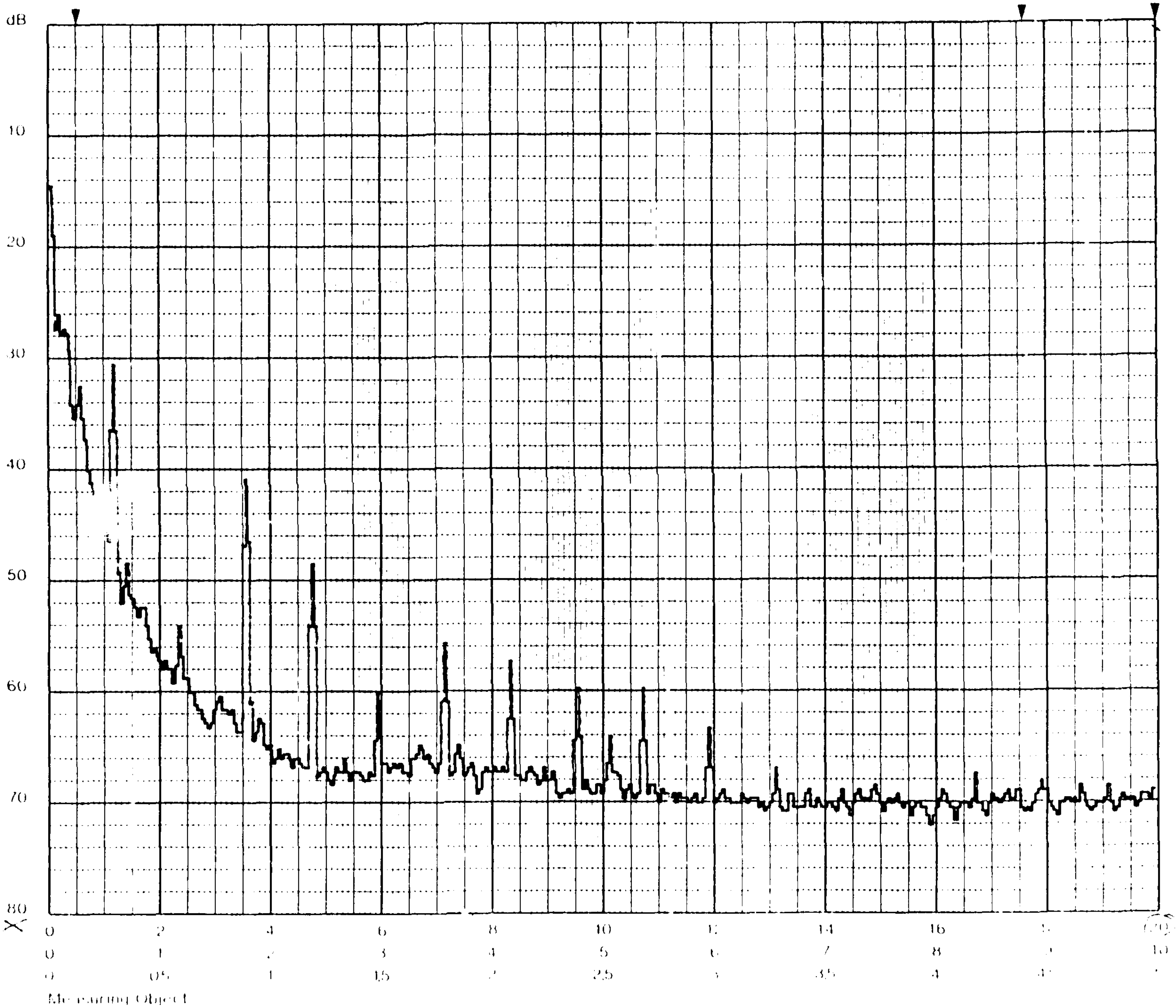
25RVA - 6E
SN P212059 Y1A

B-54

Roger
Angelo
Luchetta

Record No.
Date: 1-28-87
Sign: J Uber

Time Function Start seconds End seconds Not Expanded Expanded



QP 1002

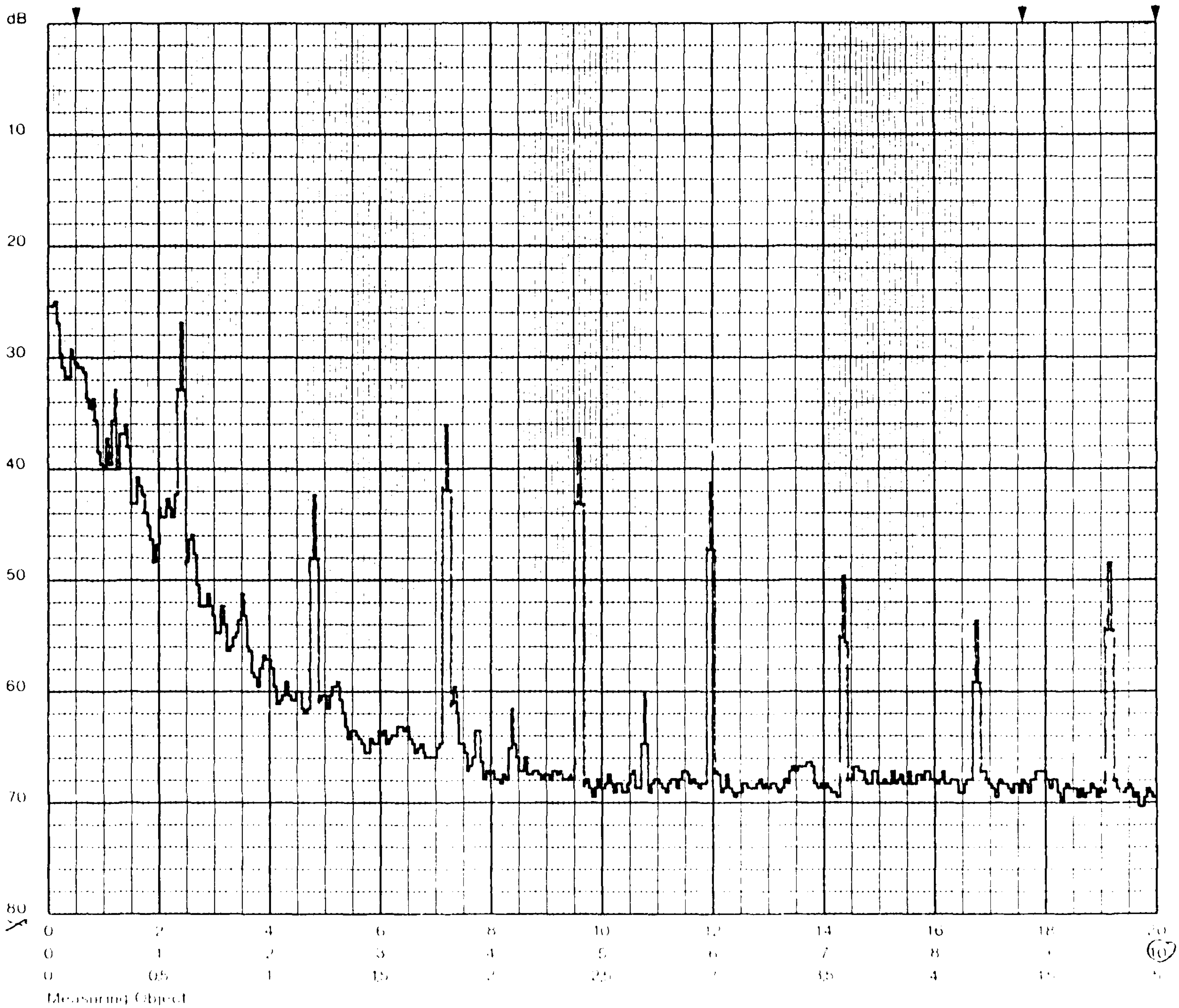
Bruel & Kjær

Time Function Start seconds End seconds Not Expanded Expanded

Full Scale Level 70
F.S. Frequency 1KHz
Weighting Hann
Average Mode Lin
No. of Spectra 64

Comments:
132v - Left - Center
Position 1

25KVA - GE
SN PD17059-4ZA



B-55

Roger
Angelo
Lichela

Record No.
Date 1-25-87
Sign J. Uher

QP 1002

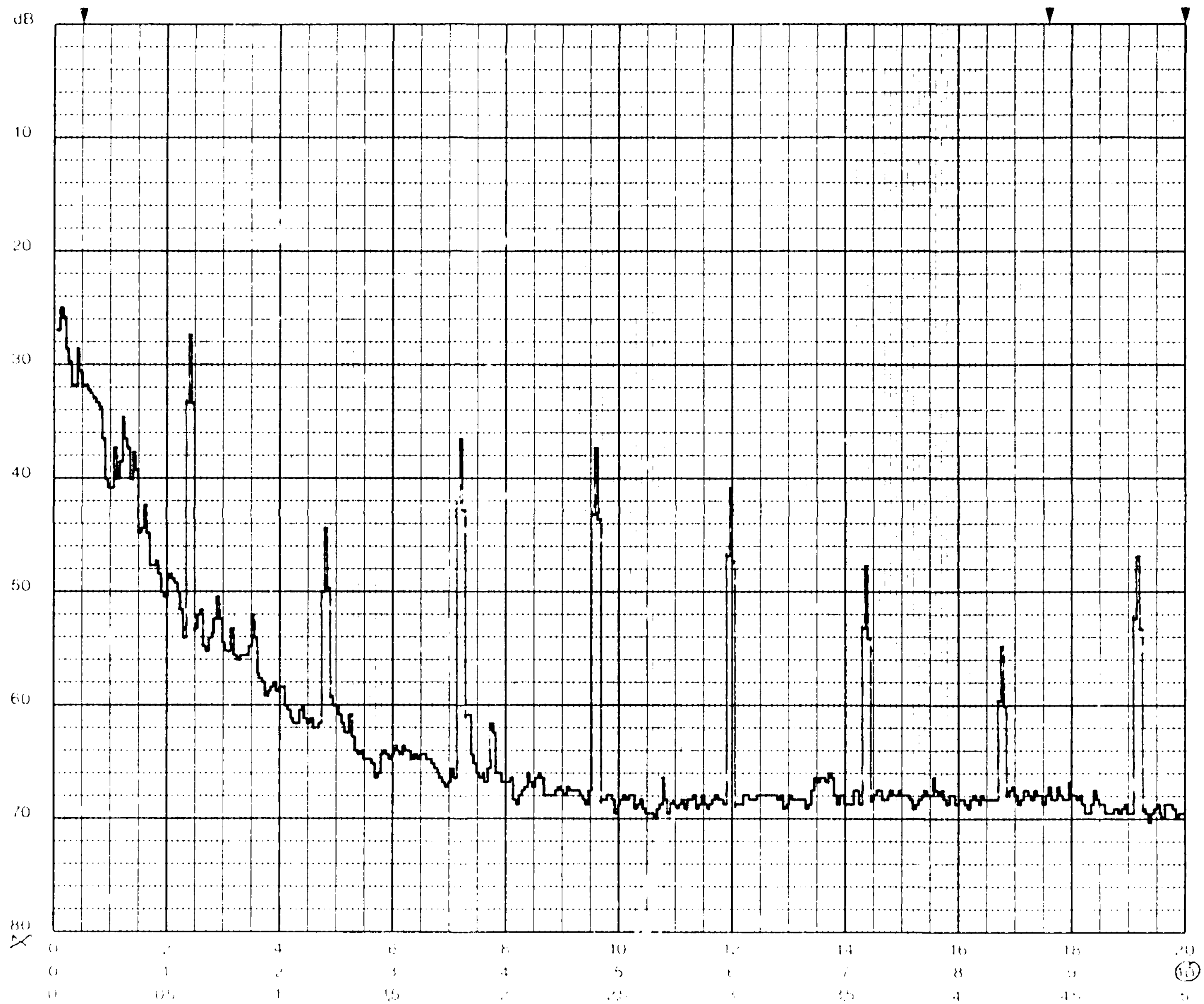
Bruel & Kjær

Time Function Start seconds End seconds Not Expanded Expanded

Full Scale Level 70
F S Frequency 1 KHz
Weighting Hann
Average Mode Lin
No of Spectra 64

Comments
132v - Right-Center
Position 1

25KVA-GE
S.N PJ17059-YZA



B-56

Roger Angel Llueleta

Record No
Date: 1-28-87
Sign: J. Uler

OP 1002

Bruel & Kjær

Full Scale Level 70
F. S. Frequency 1KHz
Weighting Hann
Average Mode Lin
No of Spectra 64

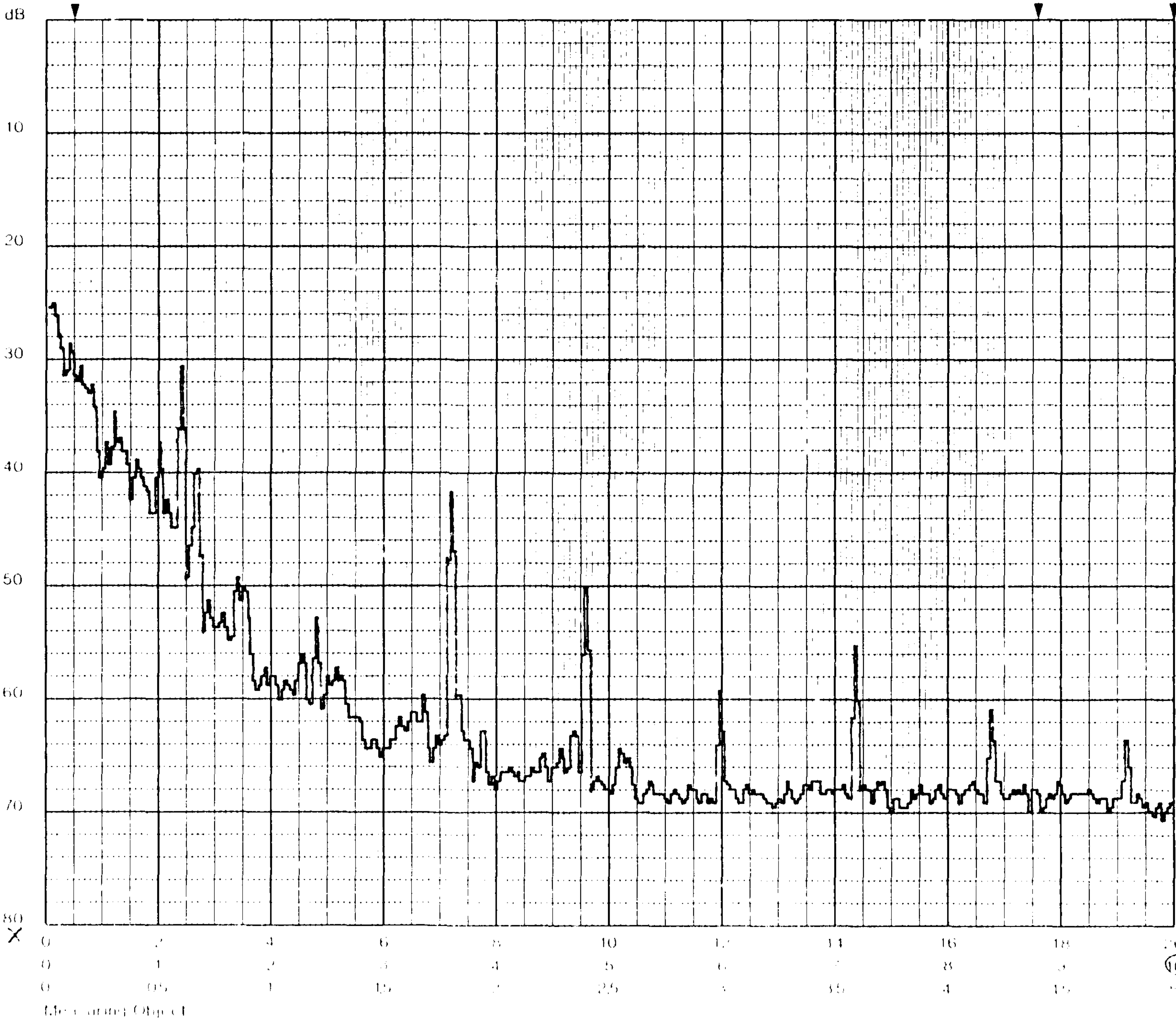
Comments
120v Right-Center
Position 1

25KVA - GE
SN P217059-42A

Roger
Angelo
Lucheta

Record No
Date: 1-28-87
Sign J. Uber

Time Function Start seconds End: seconds Not Expanded: Expanded



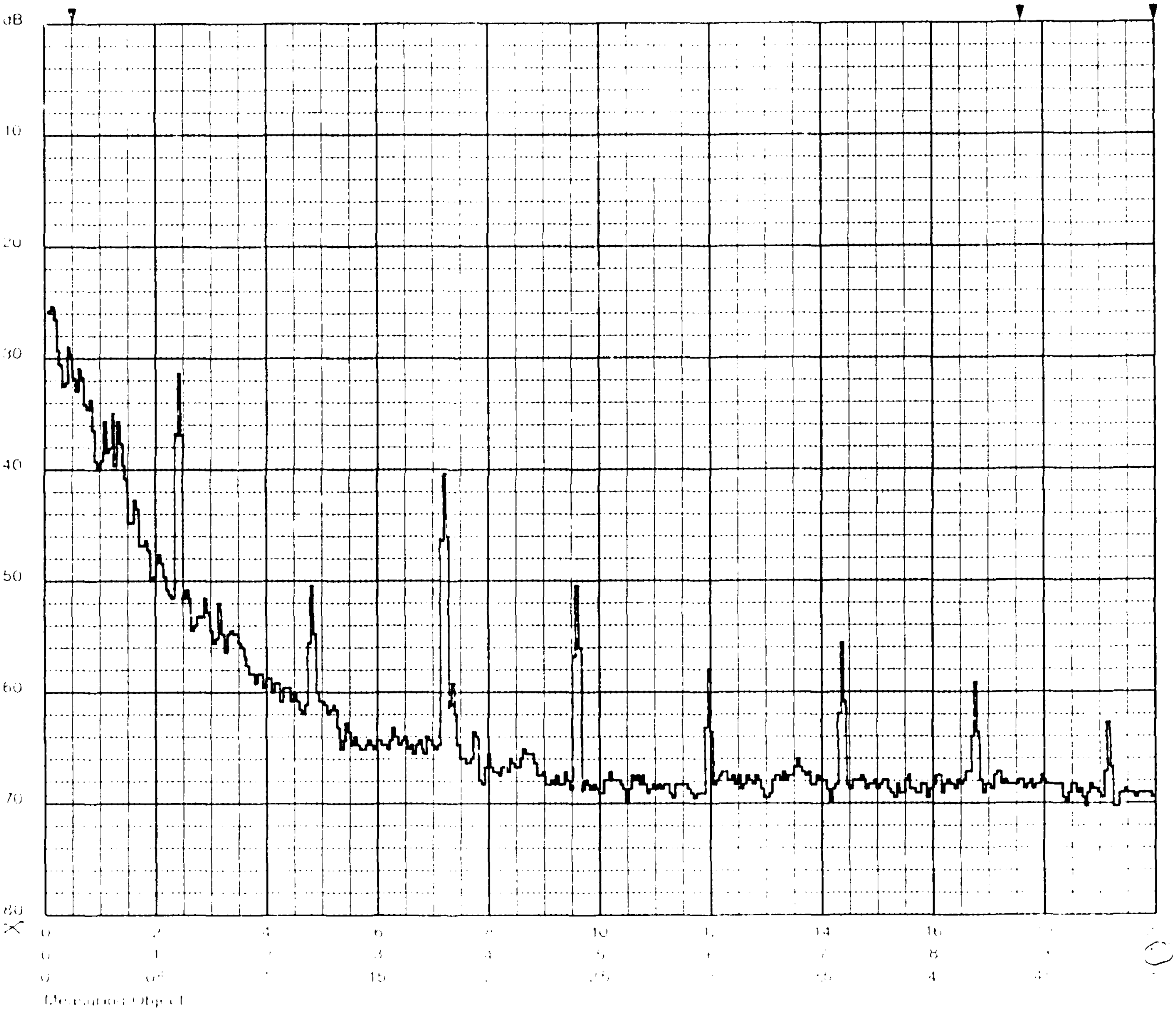
QP 100

Bruel & Kjær

Full Scale Level 70
F S Frequency 1KHz
Weighting Hann
Average Mode Lin
No of Spectra 64

Comments
120v Left-Center
Position 1

25KVA - GE
SN P317059-YZA



Roger Angelo Lucheta

Record No
Date 1-25-87
Sign J Zilber

B-58

QP 1002

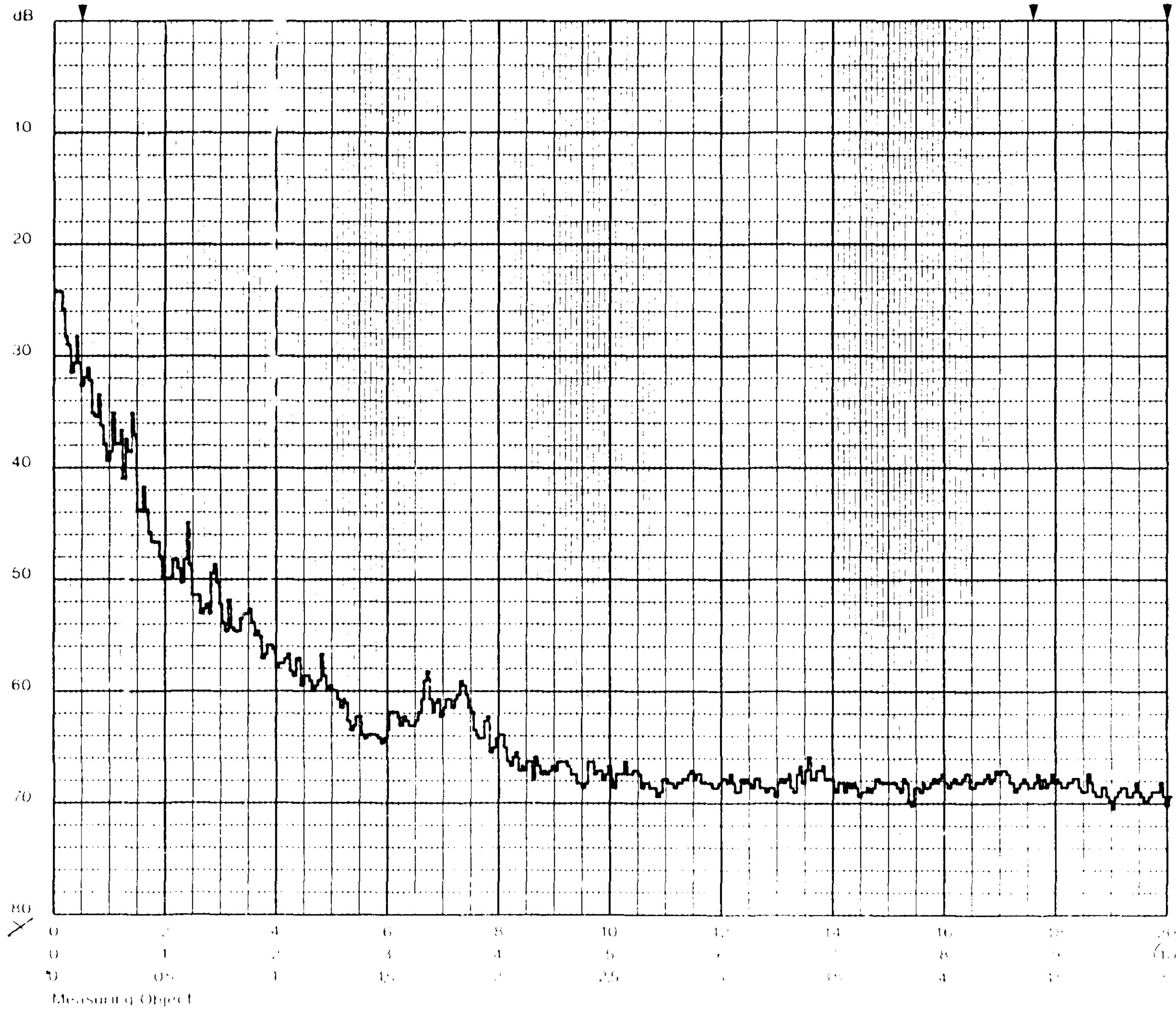
Bruel & Kjær

Time Function Start seconds End seconds Not Expanded Expanded

Full Scale Level 70
F. S Frequency 1KHz
Weighting Hann
Average Mode Lin
No of Spectra 64

Comments Ambient
Position 1

3.5KVA-GE
S/N P2170592-4ZA



B-59

Roger
Angela
Lucheta

Record No.
Date 1-28-87
Sign J. Uber

QP 1002

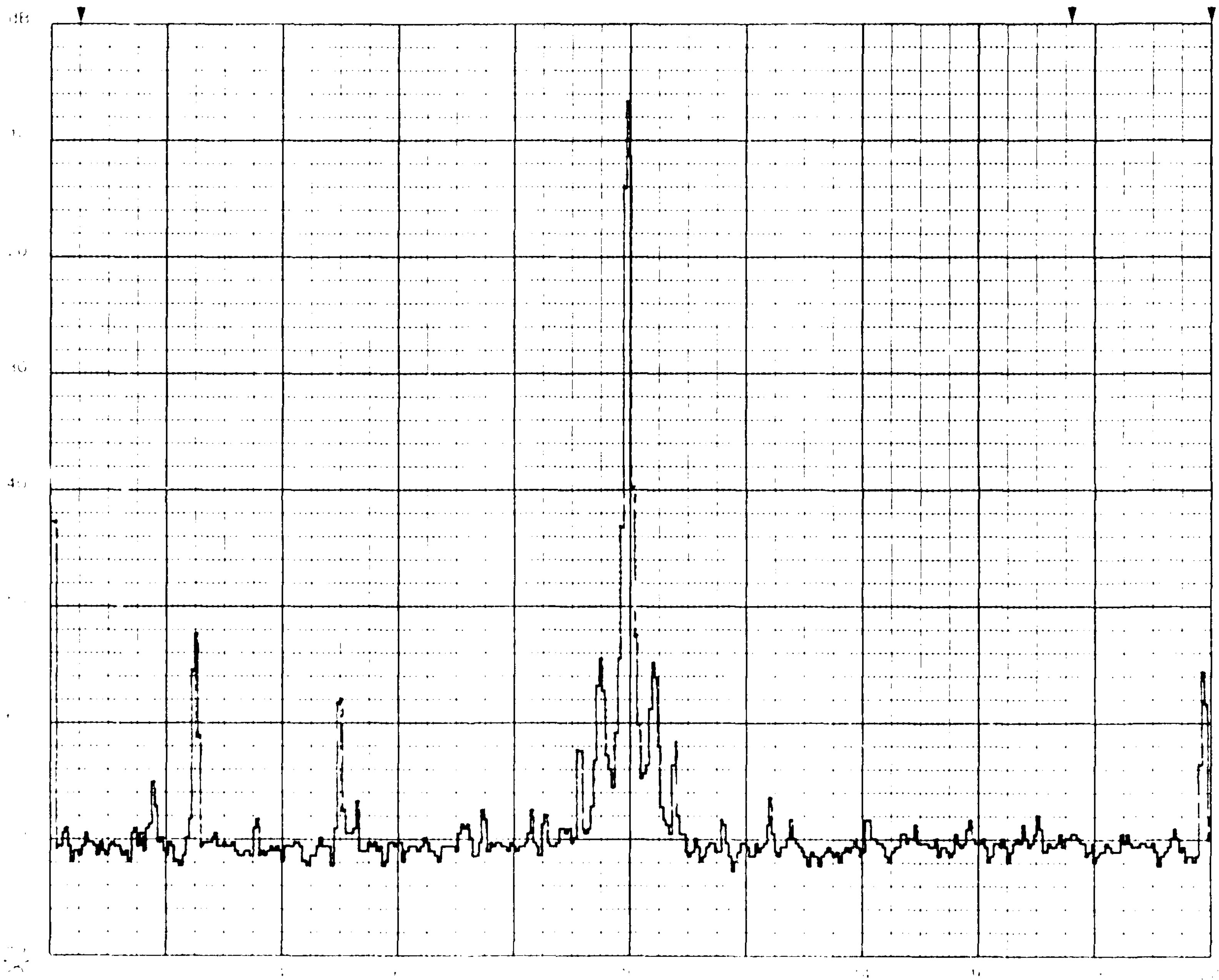
Brüel & Kjær

Not Expanded   Expanded

Full Scale Level 130
F.S. Frequency 500
Weighting Hann
Average Mode Lin
No. of Spectra 64

Comments
Calibration
250Hz - 123.7dB

25KVA GE
SN P217059-YZA



Roger
Angelo
Lucheta

Record No.
Date 28-87
Sign J. Elber

APPENDIX A.4

RIV TEST REPORT

TEST RECORD Athens **LABORATORY** D.T.D. LAB. № 01097 -1

SUBJECT General Electric Amorphous Metal Core transformer

TO DETERMINE Radio Influence Voltage tests on 2 units

CUSTOMER ACT

S. O. **L-SPEC.** **TIMING CURVE** **SERIAL**

TEMPERATURE DRY BULB | WET BULB | BAROMETER | ABSOLUTE HUMIDITY | RELATIVE AIR DENSITY

(2) General Electric Amorphous Metal Core Transformers [illegible] 2-3-87

A) P217061-YZA 25KVA ~~7200~~ 4160V Y 120/240 AL-AL mfg date Dec 86 HV [illegible] 75KV
36[illegible]A25LA [illegible] P217061-YZA

RIV test

H1 at 4160V - 0 microvolts H2 at 4160V - 0 μvolts
5000V - 0 microvolts 5000V - 0.25 μvolts

B) P217060-YZA 25KVA 4160/7200Y 120/240 AL AL mfg date Dec 86 HV [illegible] 75KV 2.5% [illegible]

RIV test

H1 at 4160V - 0 microvolts H2 at 4160V - 0 μvolts
5000V - 0 microvolts 5000V - 0 μvolts

C) P217059-YZA 25KVA 4160/7200Y 120/240 AL AL mfg date Dec 86 HV [illegible] 75KV [illegible]

H1 at 4160V - 0 μvolt H2 at 4160V - 0 μvolt
5000V - 0 μvolts 5000V - 0 μvolts

cont
(C) (measured at 200 [illegible] 240V [illegible]

PREVIOUS TEST PAGE Kell [illegible] TESTED BY | [illegible] REPORTED BY | [illegible] ENGINEER | 2-3-87 DATE

APPENDIX A.5

SHORT CIRCUIT TEST REPORTS

COOPER INDUSTRIES

McGRAW-EDISON
POWER SYSTEMS

Mr. Dorman Whitley
Westinghouse Electric Corporation
Newton Bridge Road
Athens, GA 30613

January 16, 1987

Subject: Distribution Transformer Test Report

Dear Dorman,

Enclosed is the test report covering the Short Circuit test on one General Electric™ Distribution Transformer. The tests were performed on January 16, 1987 at the McGraw-Edison Technical Center in Franksville, WI.

McGraw-Edisons' or Cooper Industries' company name may be used in promotional literature only if written permission is received for each complete copy of promotional material received.

It was a pleasure testing for you Dorman and we look forward to seeing you in the future.

Sincerely,

Ross Daharsh

Ross Daharsh
Manager, Power Test Laboratories

1-(414)-835-1560

TECHNICAL CENTER
11131 Adams Road
PO Box 100
Franksville, WI 53126
414/835-2921

COOPER
INDUSTRIES

McGRAW-EDISON POWER SYSTEMS

WESTINGHOUSE ELECTRIC CORP.

SHORT CIRCUIT TESTS ON

ONE GENERAL ELECTRIC™ DISTRIBUTION TRANSFORMER

Performed By:

McGraw-Edison Power Testing Laboratories
McGraw-Edison Company
Division of Cooper Industries
11131 Adams Road
Franksville, WI 53126

Test Date: January 16, 1987

TECHNICAL CENTER

11131 Adams Road
PO Box 100
Franksville, WI 53126
414/835-2921

Research Reports

INTRODUCTION:

The test program consisted of a standard ANSI C57.12.90-1980 Short Circuit Test Series on one General Electric™ 25 KVA Transformer, Serial Number P217059 YZA. This transformer had a Primary Voltage of 4160/7200 WYE and a Secondary Voltage of 120/240. The nameplate impedance was 2.51 % at 85° C. The test program was performed at the McGraw-Edison Technical Center in Franksville, WI under the direction of Mr. Dorman Whitley from the Westinghouse Electric Corporation. The test was performed on January 16, 1987.

PROCEDURE:

The transformer was impedance checked before, during and after the Short Circuit Tests using the classical E/I method. 5 Amperes of current was circulated in the secondary winding with the primary open circuited. The resulting secondary voltage was recorded. The current was metered with a Weston Ammeter, Model Number 370, Serial Number 6911. The voltage was monitered with a Fluke digital voltmeter Model 8000A, Serial Number 30437.

The test program was started with a magnetizing inrush current test shot followed by a reduced voltage check shot to verify impedances and metering. This was followed by the 6 ANSI test shots; 3 symmetric, 3 asymmetric; 15 cycles in length except for the long time shot required for heating. This shot was a minimum of 47 cycles in length. The impedance was checked after each test shot. The short circuit test data was recorded on a Honeywell Model 1912 Magnetic oscillograph. All recorded data has a laboratory accuracy of ±3%.

RESULTS:

The original data sheets and oscillograms from the test program are included in the report Appendix.

The transformer passed the test program with a impedance change of 5.75%.

TECHNICAL CENTER

11131 Adams Road
PO Box 100
Franksville, WI 53126
414/835-2921

McGRAW-EDISON
POWER SYSTEMS

COOPER INDUSTRIES

CERTIFICATION OF PERFORMANCE

BY

WESTINGHOUSE ELECTRIC CORPORATION

Short Circuit Tests on a 25 KVA
General Electric™ Distribution Transformer

Serial Number P217059 YZA

This is to certify that the above transformer was tested at the McGraw-Edison Thomas A. Edison Technical Center on January 16, 1987 in accordance with ANSI Standard C57.12.90-1980.
All data recorded and presented has a laboratory accuracy of ±3%.

REFERENCE OSCILLOGRAMS

87C337 - 87C345

The total impedance change was 5.75% after the completion of the 6 test shots.

By the performance of these tests McGraw-Edison does not recommend or endorse the use or application of the products, devices or systems tested.

Ross S. Daharsh

Ross S. Daharsh
Manager, Power Test Laboratories

TECHNICAL CENTER

11131 Adams Road
PO Box 100
Franksville, WI 53126
414/835-2921

McGRAW-EDISON
POWER SYSTEMS
COOPER INDUSTRIES

APPENDIX

1. Original Film Data Sheet
2. Calibration Sheet
3. Original Oscillograms

TECHNICAL CENTER

11131 Adams Road
PO Box 100
Franksville, WI 53126
414/835-2921

```
**************************************************
THIS UNIT IS SERIAL NO. 0001
IT IS A  25 KVA RATED  4.16 KV AND  6.00962 AMPS
IT IS A CATEGORY  1  TRANSFORMER
SHORT CIRCUIT IMPEDANCE IS  15.728  OHMS
<  6.78217  +jx  14.1906  >
%IZ= 2.2721   %IX=  2.05   %IR=  .979765
 40  TIMES RATED I IS  240.385 AMPS
LONG TIME TEST IS  46.25  CYCLES
MAXIMUM IMPEDANCE CHANGE IS  11.1395  PERCENT
'K' FACTOR<PK ASYM/RMS SYM> IS  1.76602
**************************************************
```

Job No. 66M87Y006C **Test Date** 1/16/87 **Request** 14-66-01

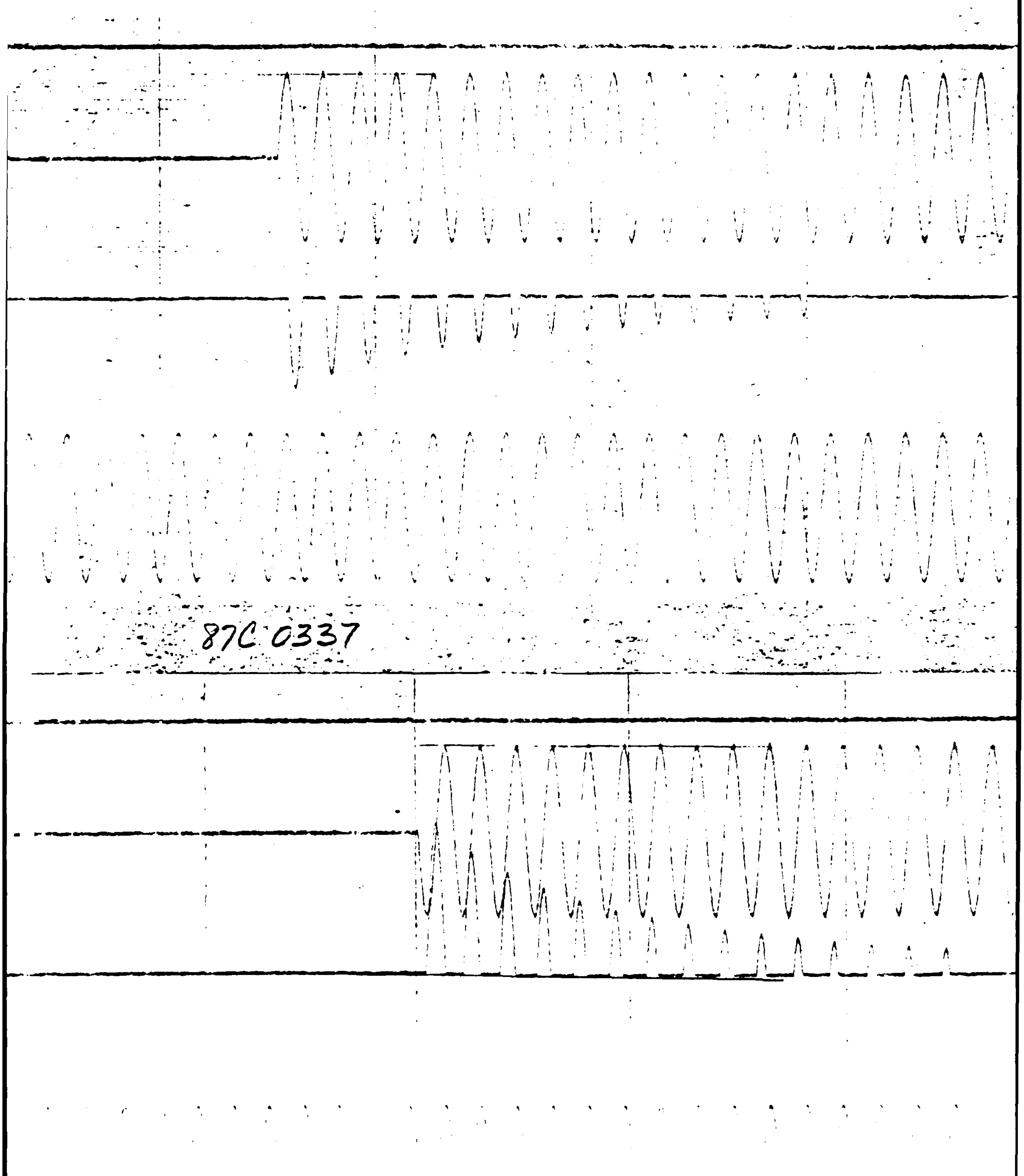
Data Read & Recorded: By, Date 1/12/87 D Guyon

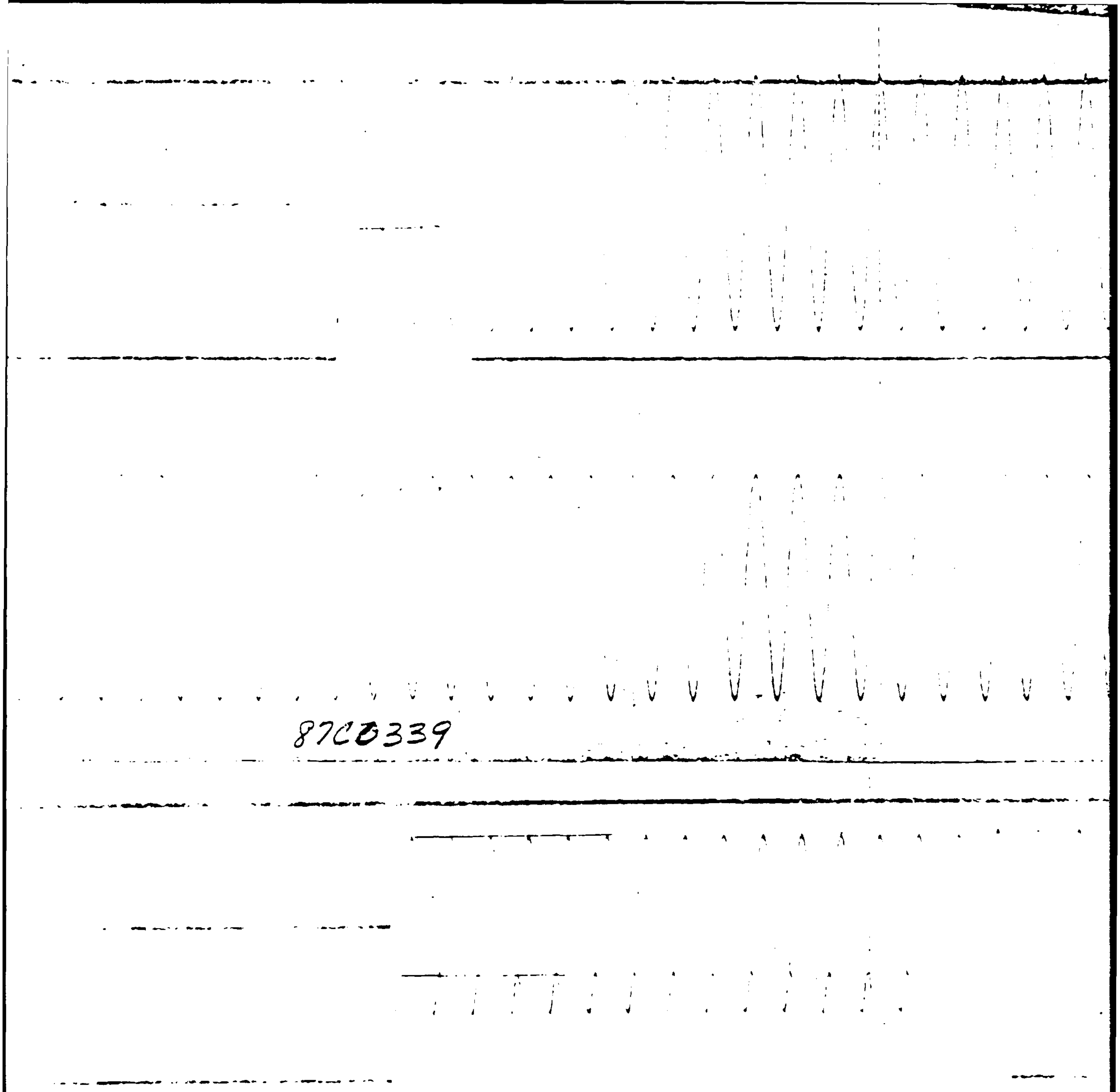
Ckt. No.	Generator				Phase	Test V.					Arc V.			Load Add			Current				FAULT I for GRD I					
	Conn.	φ-φ Kv	Elem./R	Kv/Cm		φ-φ Kv	φ-N Kv	Meter Ratio	Elem./R	Kv/Cm	Meter Ratio	Elem./R *	V/Cm	X/R	Xe	Re	Calc.	Meter Device	Elem./R	MA/Cm	Meter Device	Elem./R	A/Cm	Meter Device	Elem./R	/Cm
1	11Y	2.0	24/1.3K	1.23	A		2.0	100/1	18/1.3	1.08	–	–	–		.37	–	120	600/5 .25Ω	20/10	60	4000/5 .15Ω	17/100	2400			
					C										.37	–										
2	11Y	4.0	24/3K	2.74	A		4.0	100/1	18/3K	2.4	–	–	–		.37	–	240	600/5 .25Ω	20/50	120	"	"	"			
					C										.37	–										
3	11Y	4.16	24/3K	2.74	A		4.16	100/1	18/3K	2.4	–	–	–		.37	–	PK 100	200/5 .25Ω	20/50	PK 56.6	"	"	"	INRUSH		
					C										.37	–										

POWER TEST LABS

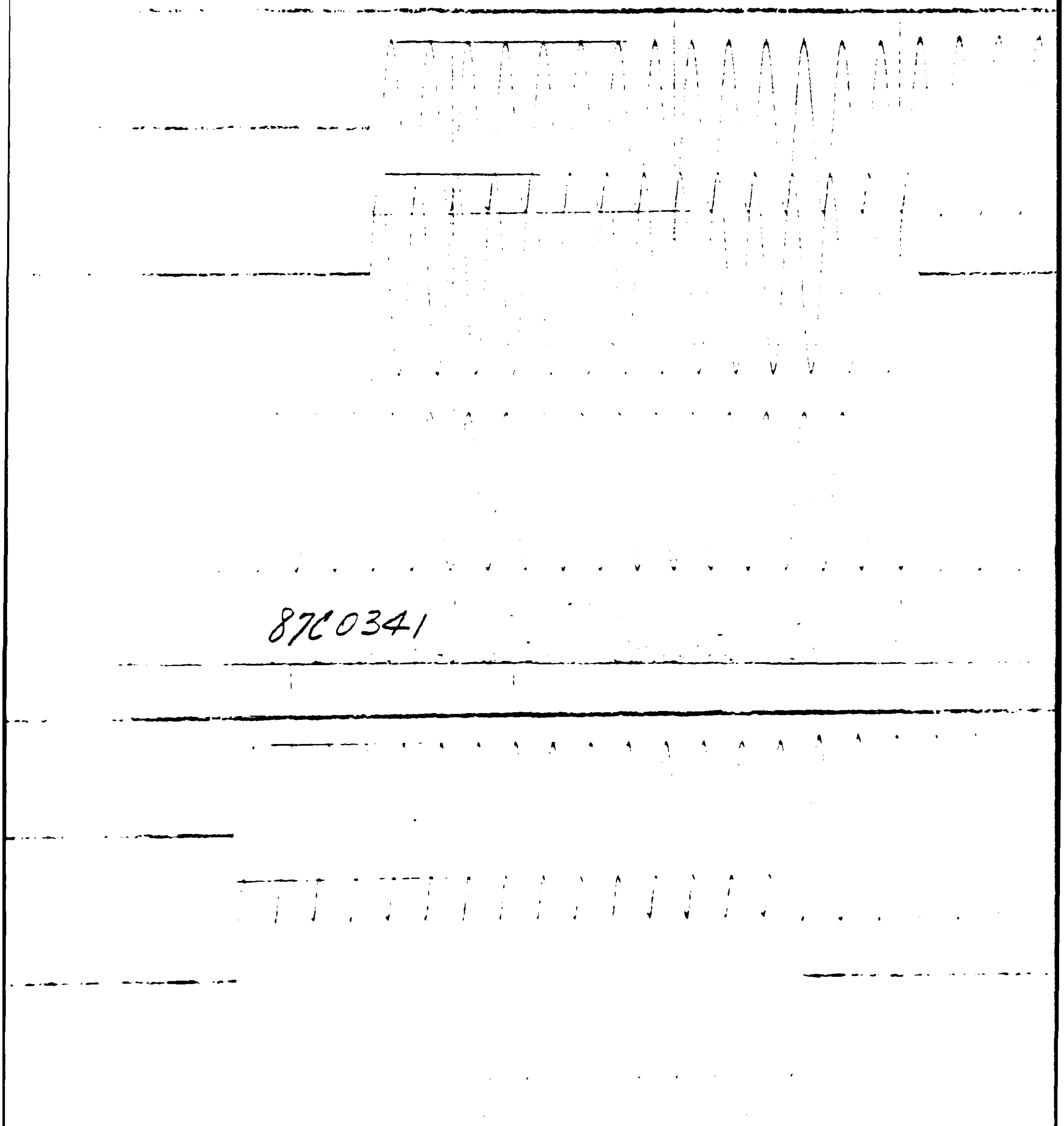
COMPANY Westinghouse Elec TEST 25kVA TRANS F.
PROJECT NO. 66MR7X006C REQUEST NO. 14-66-01
DATA BY DATE 1/16/87

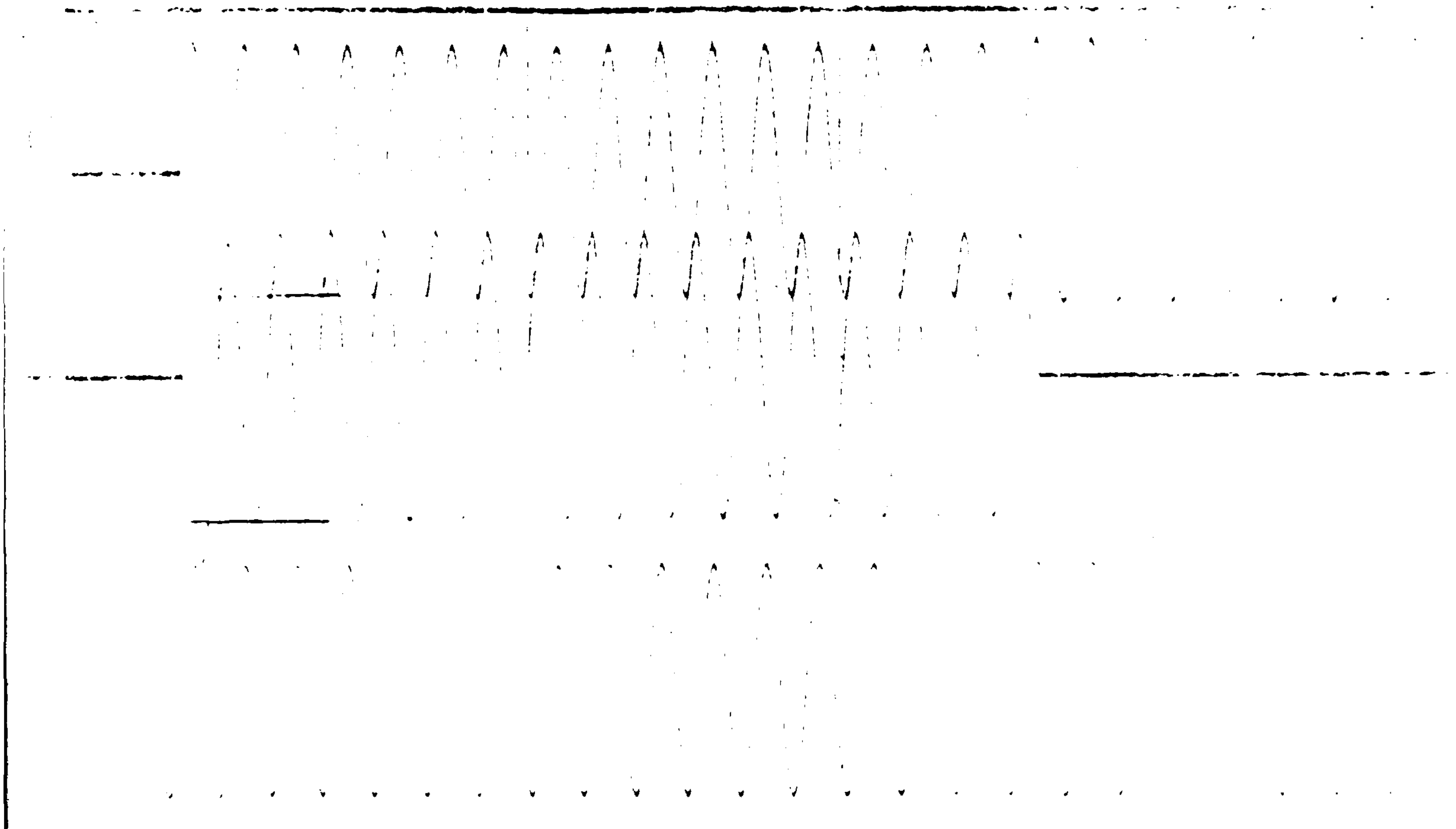
TEST NO.	CKT. NO.	SPEC. SERIAL NO.	TEST I RMS	TEST I PEAK	TEST VOLTS KV RMS	STATION VOLTS KV	TIME IN CYCLES	E	I	Z	% Z CHANGE	TYPE OF TEST	TIMES RATED AMPS	REMARKS
		P217054-YZA						81.8	5	16.36	—			Prior To Test
337	3			101.9	4.16	4.16	15							INRUSH
338	3			173.2	4.17	4.18	15	81.7	5	16.34	-.12		—	INRUSH
339	1		148	—	2.57	2.55	3.5	81.9	5	16.38	.12	1/2 SHOT	24.6	OK
340	2		237	—	3.96	4.15	15.0	82.7	5	16.54	1.10	Sym	39.44	OK
341	2		239.4	—	4.08	4.26	14.5	83.4	5	16.68	1.96	Sym	39.84	OK
342	2		240.6	—	4.18	4.38	15.0	84.2	5	16.84	2.93	Sym	40.04	OK
343	2		244.8	439.5	4.28	4.48	16.0	85.1	5	17.02	4.03	Asym	40.73	OK, K=1.795
344	2		244.8	439.5	4.32	4.52	15.5	85.7	5	17.14	4.77	Asym	40.73	OK, K= 1.795
345	2		238.8	—	4.22	4.50	49.0	86.5	5	17.3	5.75	Sym	39.74	OK


87C 0337

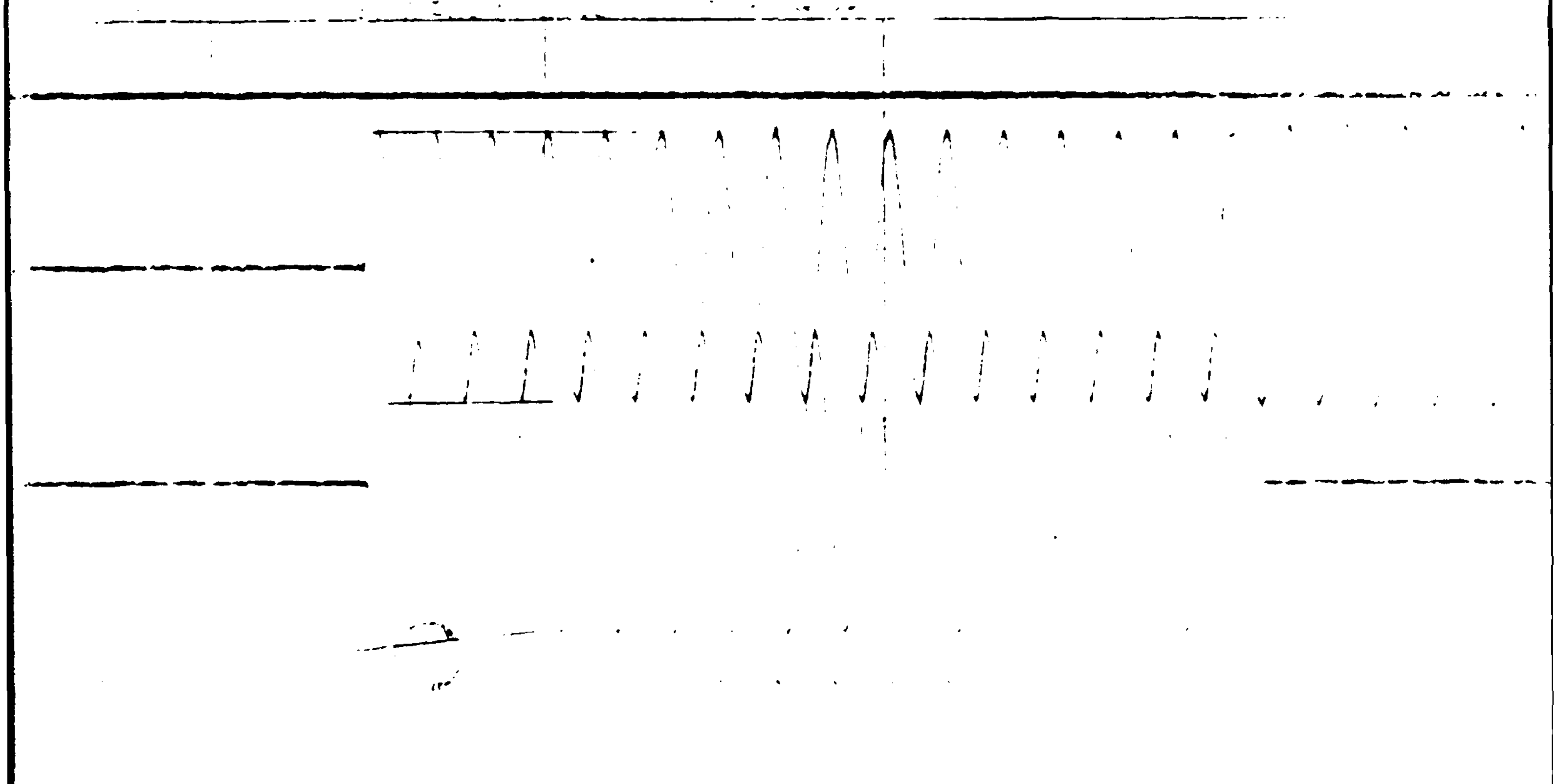


87C0340


87C0341



87C 0343



87C0344

WESTINGHOUSE DTD COMMERCIAL TEST REPORT

DATE: [illegible]-87

CONDITION: FOLLOWING SHORT CIRCUIT, SOUND LEVEL, AND RIV

STYLE: G.E. 25KVA AMORPHOUS METAL POLE TYPE

LV: 120/240 HV: 4160Y 75KV BIL SERIAL #: [illegible]

RATIO	PASS	* HV RESISTANCE (OHMS)	4.652
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01344
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	[illegible]
APPLIED POTENTIAL - HLTO	PASS	* STRAYS	[illegible]
APPLIED POTENTIAL - LHTO	PASS	* LOAD LOSS (WATTS)	324.[illegible]
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	343.[illegible]
NL LOSS (WATTS)	19.3	* % RESISTANCE	1.30
% EXCITING CURRENT	0.098	* % REACTANCE	2.22
% EFFICIENCY @ PF=1	98.6	* % IMPEDANCE	2.57
% EFFICIENCY @ PF=.9	98.3	% REGULATION @ PF=1	1.32
		% REGULATION @ PF=.9	[illegible]

TEST ENGINEER: Gregg V. Jones

GREGG V. JONES

* CORRECTED TO 85 DEGREES C

APPENDIX A.7

IMPULSE-ENERGIZED TEST REPORTS

TEST RECORD Athens **LABORATORY** Overhead D.T.D. LAB. № 01098 -1

SUBJECT full wave, chopped wave and steep front impulse on an energized

TO DETERMINE transformer

CUSTOMER ACF / NAVY

S. O. **L-SPEC.** **TIMING CURVE** **SERIAL** P217060-YZA

TEMPERATURE DRY BULB WET BULB BAROMETER ABSOLUTE HUMIDITY RELATIVE AIR DENSITY

All testing as outlined and suggested in ANSI C57.12.90-1980 Sec 10.5 specified in ?BIL test parameters as given in Table 4

Unit was energized separately with a 60 hertz generator [illegible] (feeding) from the L.V. side to the test transformer. The impulse is triggered on the "worst" side of the 60 cycle sine wave so to add together.

Test sequence and results

I 1 reduced full wave to each bushing H1 results 46.4KV H2 46.8KV (energized)

II 2 chopped waves per bushing (energized) Lab results 4 shot to H2 bushing 70.4KV, 76KV, 81.1KV, 83KV

(Generator set up for future test gap 14mm = Charge KV 47.5) 2 shots to H1 bushing 86, 88KV

stages (2 par & 5 series)

III 400 hertz 18 second duration at 2x rated voltage of transformer - lab result - passed

IV 2 steep front impulses per bushing at 135KV crest and chop at .5 microsecond

Lab results: H1 ① 135, ② 126.6KV H2 ① 134.4KV ② 136.1KV (energized)

appears to have passed

V 400 hertz 18 second duration at 2x rated voltage of transformer - lab results passed

VI 1 shot per bushing at 75KV full wave (energized)

VII 400 hertz test and applied 26KV HV insulation test - Passed

10KV L.V. insulation test passed

PREVIOUS TEST PAGE [illegible] TESTED BY Bill [illegible] REPORTED BY [illegible] ENGINEER 2-11-87 DATE

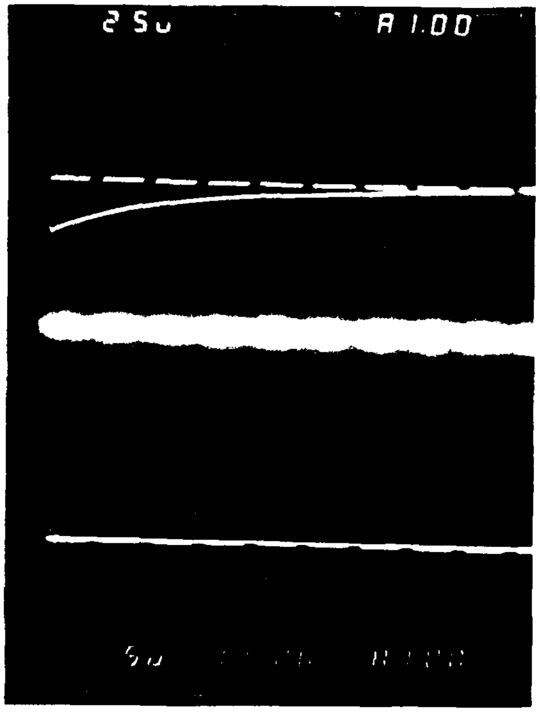


Figure A.7.1A. Reduced Full Wave - Bushing 1

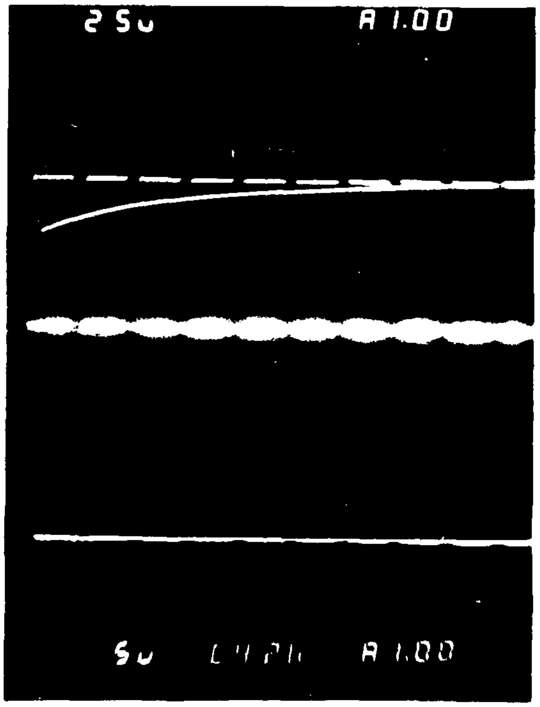


Figure A.7.1B. Reduced Full Wave - Bushing 2

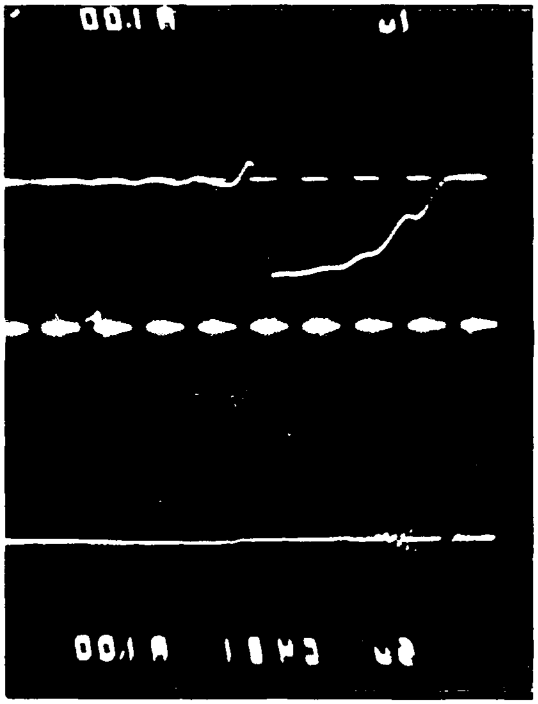


Figure A.7.2A. Chopped Wave - Bushing 1
Shot 1

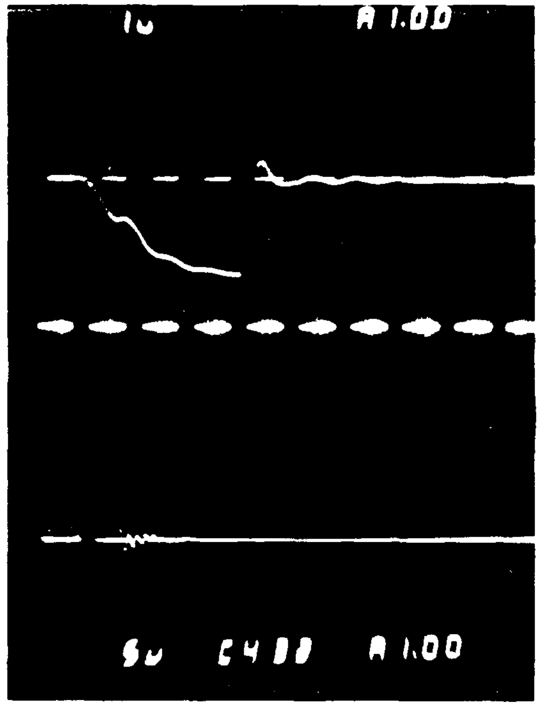


Figure A.7.2B. Chopped Wave - Bushing 1
Shot 2

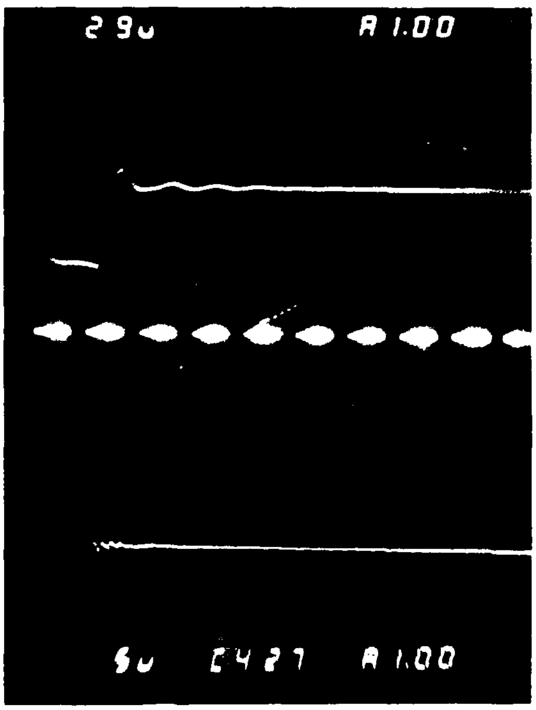


Figure A.7.2C. Chopped Wave - Bushing 2
Shot 1

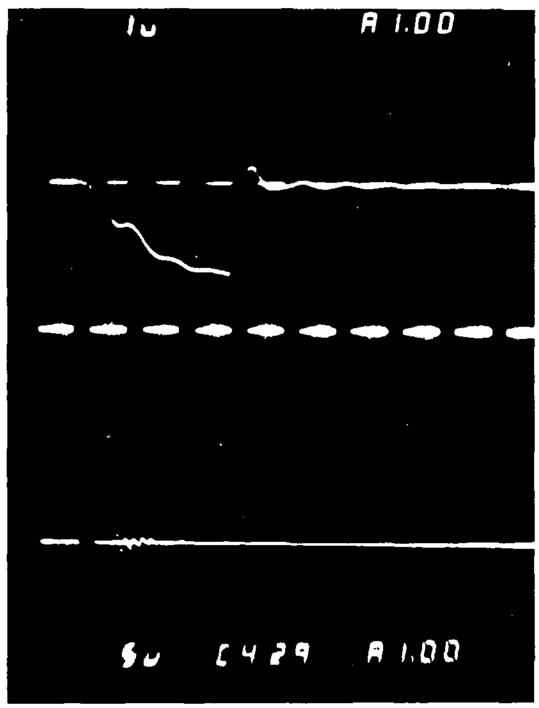


Figure A.7.2D. Chopped Wave - Bushing 2
Shot 2

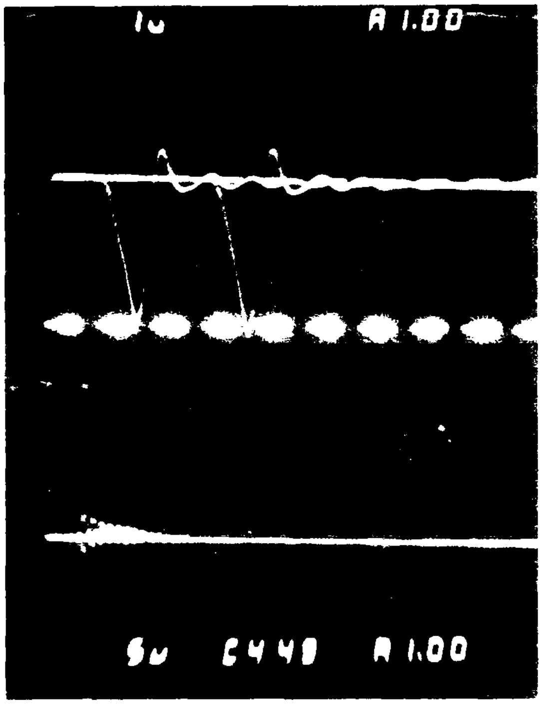


Figure A.7.3A. Front of Wave - Bushing 1

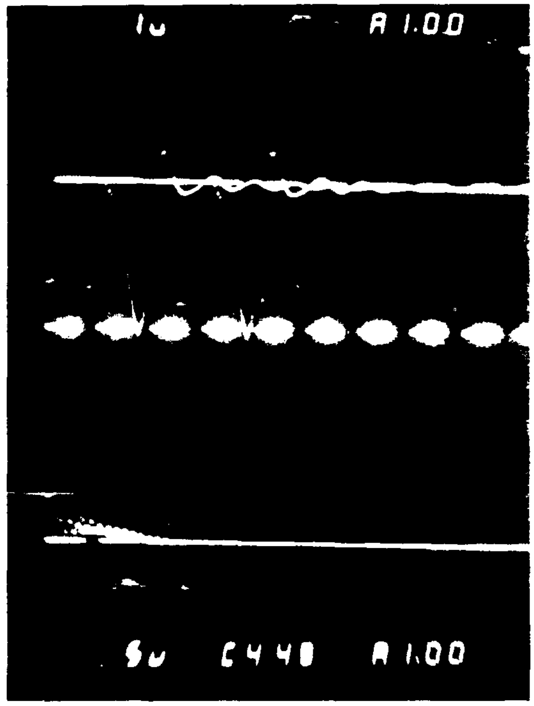


Figure A.7.3B. Front of Wave - Bushing 2

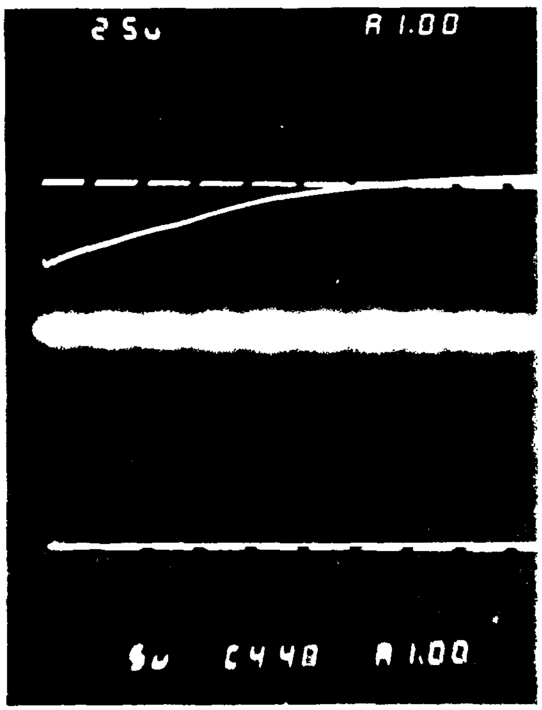


Figure A.7.4A. Full Wave - Bushing 1

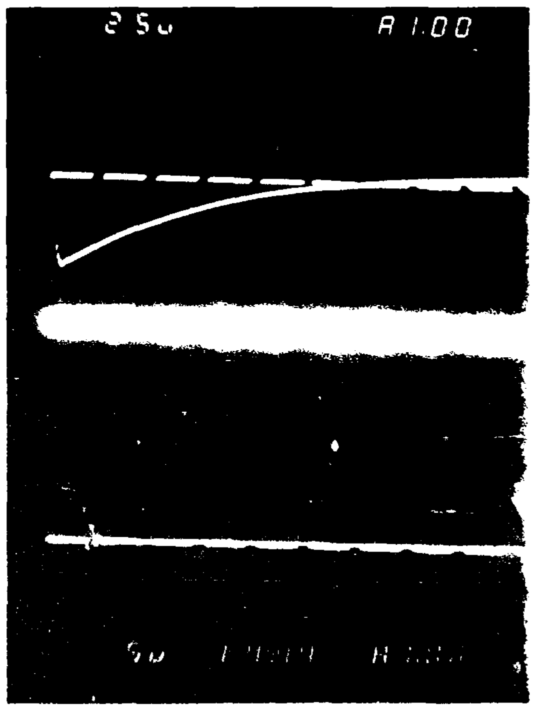


Figure A.7.4B. Full Wave - Bushing 2

APPENDIX A.8

SAFE TRANSIT TEST REPORTS

TABLE B.-1 [illegible]
[illegible]
START TIME [illegible]
TRANSFORMER SERIAL NO. [illegible]

0 HOURS

[illegible]	Vavg	Vrms	I (AMPS)	%I	TW (WATTS)
[illegible]	[illegible]	108	[illegible]	[illegible]	[illegible]
120	100	120	0.214	0.10	[illegible]
132	110	132	[illegible]	0.19	[illegible]

1 HOURS

[illegible]	Vavg	Vrms	I (AMPS)	%I	TW (WATTS)
108	99	108	0.177	0.07	15.9
120	100	120	0.213	0.10	19.5
132	110	132	0.353	0.19	27.9

2 HOURS

[illegible]	Vavg	Vrms	I (AMPS)	%I	TW (WATTS)
108	[illegible]	108	0.172	0.07	15.3
120	100	120	0.212	0.10	19.[illegible]
132	110	132	0.353	0.19	27.9

4 HOURS

[illegible]	Vavg	Vrms	I (AMPS)	%I	TW (WATTS)
1[illegible]	[illegible]	108	0.172	[illegible]	1[illegible]
[illegible]	100	120	0.211	[illegible]	[illegible]
[illegible]	110	132	[illegible]	0.19	[illegible]

[illegible] Gregg V. Jones
GREGG V. JONES

WESTINGHOUSE DTD COMMERCIAL TEST REPORT

DATE:02/10/87

CONDITION: FOLLOWING FOUR HOUR SHAKE

STYLE: G.E. 25kVA AMORPHOUS METAL POLE TYPE FOR

LV: 120/240 HV: 4160: 75kV BIL SERIAL #:P217059-YZA

RATIO	PASS	* HV RESISTANCE (OHMS)	4.632
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01344
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	313.2
APPLIED POTENTIAL - HLIC	PASS	*STRAYS	3.8
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	317.0
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	336.2
NL LOSS (WATTS)	19.2	* % RESISTANCE	1.27
% EXCITING CURRENT	0.0968	* % REACTANCE	2.15
% EFFICIENCY @ PF=1	98.7	* % IMPEDANCE	2.50
% EFFICIENCY @ PF=.8	98.3	% REGULATION @ PF=1	1.29
		% REGULATION @ PF=.8	2.31

TEST ENGINEER: Gregg V. Jones

GREGG V. JONES

* CORRECTED TO 85 DEGREES C

WESTINGHOUSE DTD COMMERCIAL TEST REPORT

DATE:02/11/97

CONDITION: FOLLOWING FOUR FOOT DROP

STYLE: G.E. 25KVA AMORPHOUS METAL POLE TYPE

LV: 120/240 HV: 4160Y 75KV BIL SERIAL #:P217059-YZA

RATIO	PASS	* HV RESISTANCE (OHMS)	4.662
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01354
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	315.3
APPLIED POTENTIAL - HLIC	PASS	* STRAYS	8.7
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	324.0
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	342.8
NL LOSS (WATTS)	18.8	* % RESISTANCE	1.30
% EXCITING CURRENT	0.11	* % REACTANCE	2.21
% EFFICIENCY @ PF=1	98.6	* % IMPEDANCE	2.56
% EFFICIENCY @ PF=.8	98.3	% REGULATION @ PF=1	1.32
		% REGULATION @ PF=.8	2.77

TEST ENGINEER: Gregg V. Jones

GREGG V. JONES

* CORRECTED TO 85 DEGREES C

APPENDIX A.10

COLD LOAD PICKUP TEST REPORTS

TEST RECORD Althen **LABORATORY** Overhead D.T.D. LAB. № 01099 -1

SUBJECT Cold Load pickup test on a 25KVA GE Amorphous core transformer

TO DETERMINE load handling ability at cold temperature

CUSTOMER ACT /NAVY

S. O. **L-SPEC.** **TIMING CURVE** **SERIAL** P217061-YZA

TEMPERATURE DRY BULB WET BULB BAROMETER ABSOLUTE HUMIDITY RELATIVE AIR DENSITY

date	time	oil *temp	chamber temp	% Load	A	V	W	hours	
2/12	7:45	-34	-38	200	12.00	188.5	788	0	start up 200% loading
	8:15	-33	-38	200	12.06	194	930	0.5	
	8:30	-30	/	200	12.1	196	985	0.75	
	8:45	-25	-38	200	12.04	196	1000	1.0	
	9:30	-8	-38	200	12.03	198	1066	1.75	
	9:45	-3	-38	200	12.01	198.5	1077	2.0	Complete 2 hours continuous 200% loading
	BEGINS 6 HOURS AT 100% LOADING								
	9:45	-3	-38	100	6.00	100.0	276	0	
	11:45	-3	-38	100	6.00	98.5	240	2	
	1:30P	-6	-38	100	6.00	97.8	244	3.15	
	2:15	-7	-38	100	6.00	96.8	238.8	4.30	
	3:00	-7	-38	100	6.03	97.4	241.1	5.25	
	3:45	-8	-38	100	6.02	97.2	241.1	6.0	

* thermocouple temperature indicator wire approx 1 inch above top [illegible] center [illegible]

PREVIOUS TEST PAGE [signature] TESTED BY [signature] REPORTED BY [signature] ENGINEER [illegible] DATE

UNCLASSIFIED INFORMATION EXEMPT [illegible]

WESTINGHOUSE DTD COMMERCIAL TEST REPORT

DATE: 12/17/87

CONDITION: FOLLOWING COLD LOAD PICK UP

STYLE: G.E. 25kVA AMORPHOUS METAL POLE TYPE

LV: 120/240 HV: 4160 75kV BIL SERIAL #:P217051-Y2A

RATIO	PASS	* HV RESISTANCE (OHMS)	4.522
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01304
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	306.4
APPLIED POTENTIAL - HLIC	PASS	*STRAYS	12.6
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	319
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	337.6
NL LOSS (WATTS)	18.6	* % RESISTANCE	1.28
% EXCITING CURRENT	0.18	* % REACTANCE	2.12
% EFFICIENCY @ PF=1	98.7	* % IMPEDANCE	2.48
% EFFICIENCY @ PF=.8	98.3	% REGULATION @ PF=1	1.3
		% REGULATION @ PF=.8	2.3

TEST ENGINEER: Gregg V. Jones

GREGG V. JONES

* CORRECTED TO 85 DEGREES C

APPENDIX A.11

SATURATION/REGULATION/EFFICIENCY TEST REPORTS

TEMPERATURE TEST RECORD
WESTINGHOUSE FORM 4857K

DTD LAB PAGE № 00733

TRANSFORMER TYPE: [illegible] TEMPERATURE TEST ON 25 K.V.A. TRANSFORMER STYLE [illegible]

CONNECTED H.V. 4160 VOLTS L.V. 120/240 VOLTS

LOAD H.V. 100 % 6.00 AMPS. L.V. 104 AMPS 60 CYCLES

WATTS PER LB. H.V. 7.68 L.V. 5.88 MAGNETIZED VOLTS CYCLES ON V

GALLONS OIL CIRCUIT TEST METHOD Compromise NO OF RADIATORS 0 NO TUBES

REMARKS NAVY LACE Project Amorphous cores.

SERIAL # P217061

TIME AFTER SHUTDOWN MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.	AVE. WIND. TEMP.	TIME AFTER SHUTDOWN MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP BY RES	CORRECTION TO SHDN.	AVE. WIND. TEMP.
		25.5			3.77						25.5			.01062			
1	15				4.535	76.00	0.65	76.65	2	00				.01275	75.74	0.76	76

CALC. H.V. WINDING RISE $76.65 - 66.8 = 9.85$ DIFF / $9.85 + 39.2 = 49.05°C$ winding rise

CALC. L.V. WINDING RISE $76.5 - 66.8 = 9.7°C$ DIFF / $9.7 + 39.2 = 48.9°C$ winding rise

HOURS	TIME	TEMPERATURE READINGS TOP OIL	BTTM. OIL	AMB. OIL	TEMPERATURE RISE TOP OIL	BTTM. OIL	WATTMETER AND VOLTMETER
Steady State		67.3		28	39.2		← Compromise - St State
1		67.3		28	39.2		– Begin 2 hrs at rated I
2		66.8		28	38.7		← Shutdown

LOAD TEST AT 25.5 C

AMPS 6.00

VOLTMETER 986

WATTMETER 259.45

Tale - Magtrol analyzer

NO LOAD TEST

(T.W.) WATTMETER 18.32

(A.W.) VOLTS 240 X AMPS .199

41.76 VA

TIME CONSTANT

63.3 X °C OIL RISE =

TIME CONSTANT =

HRS. MIN.

	Begin Compromise	Compromise St State	Begin 2 hrs at rated I	Shutdown
Ammeter	6.18	6.18	6.00	6.00
Voltmeter	102	106	102.8	102.8
Wattmeter	281.8	331.2	311.4	307.4

AL TYPE CONDUCTOR H.V.

AL TYPE CONDUCTOR L.V.

CALCULATED COMPROMISE CURRENT 6.18

OTHER REMARKS

this same unit was tested in back-back ... as shown on P 00726

TEST REQUESTED BY Greg Jones DATE TESTED 3-11-87 BY Bill Belvan L.SPEC # N/A

TEMPERATURE TEST RECORD
WESTINGHOUSE FORM 4857K

DTD LAB PAGE № 00734

TRANSFORMER TYPE: Pole TEMPERATURE TEST ON 25 KVA TRANSFORMER STYLE Gen Electric

CONNECTED H.V. 4160 VOLTS L.V. 120/240 VOLTS

LOAD H.V. 50% 3.00 AMPS L.V. 52 amps (104 ÷ 2) AMPS 60 CYCLE

WATTS PER LB. H.V. 50% 4.32 L.V. 3.3 MAGNETIZED VOLTS CYCLES ON

GALLONS OIL CIRCUIT TEST METHOD Compromise NO. OF RADIATORS NO. TUBES

REMARKS.

SERIAL # P217061

TIME AFTER SHUTDOWN MIN. SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.	AVE. WIND. TEMP.	TIME AFTER SHUTDOWN MIN. SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.
	25.5			3.77					25.5			.01062		
1 05				4.055	44.44	0.31	44.75	1 45				0.140	43.9	0.384

CALC. H.V. WINDING RISE $44.75 - 41.2 = 3.55$ Diff / $3.55 + 14.3 = 17.85°C$ winding rise

CALC. L.V. WINDING RISE $44.28 - 41.2 = 3.08$ DIFF / $3.08 + 14.3 = 17.38°C$ winding rise

HOURS	TIME	TOP OIL	BTTM. OIL	AMB.	TOP OIL	BTTM. OIL	WATTMETER AND VOLTMETER
Steady							
Volts at 50%		42.1		27.8	14.3		50% Compromise Current
C		42.1		27.8	14.3		begin 3 hrs at rated
2		41.2		27.7	13.5		Shutdown

	Compromise at line	Begin 3 hrs at rated I	Shutdown
Ammeter	3.33	3.00	[illegible]
Voltmeter	55.75	50.17	50.46
Wattmeter	86.1	69.5	[illegible]

LOAD TEST AT C

AMPS

VOLTMETER

WATTMETER

NO LOAD TEST

(T.W.) WATTMETER

(A.W.) VOLTS X AMPS VA

TIME CONSTANT

63.3 X C OIL RISE

TIME CONSTANT HRS MIN

AL TYPE CONDUCTOR H.V.

AL TYPE CONDUCTOR L.V.

CALCULATED COMPROMISE CURRENT 3.33

OTHER REMARKS

TEST REQUESTED BY Greg Jones DATE TESTED 3-12-87 BY Bill Beltran L.SPEC # N/A

TEMPERATURE TEST RECORD
WESTINGHOUSE FORM 4857K

DTD LAB PAGE № 00735

TRANSFORMER TYPE: P-E TEMPERATURE TEST ON 25 K.V.A. TRANSFORMER STYLE [illegible] Electric
CONNECTED H.V. 4160 VOLTS L.V. 120/240 VOLTS
LOAD H.V. 150% 9.0 AMPS. L.V. 156 AMPS. 60 CYCLES
WATTS PER LB. H.V. 17.3 L.V. 13.23 MAGNETIZED VOLTS CYCLES ON. V
GALLONS OIL CIRCUIT TEST METHOD Compromise NO. OF RADIATORS 0 NO. TUBES 0
REMARKS NAVY - ACT
SERIAL # P217061

TIME AFTER SHUTDOWN MIN.	SEC.	TEMP. H.V. WINDING BY RESISTANCE AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.	AVE. WIND. TEMP.	TIME AFTER SHUTDOWN MIN.	SEC.	TEMP. L.V. WINDING BY RESISTANCE AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.	AVE. WIND. TEMP.
		25.5			3.77						25.5			.01062			
1	23				5.265	124.83	1.6	126.43	2	15				.01470	121.73	1.85	12[illegible]

CALC. H.V. WINDING RISE $126.43 - 106.4 = 20.0°$ DIFF / $20 + 78.6 = 98.6°C$ Winding rise 150%

CALC. L.V. WINDING RISE $123.6 - 106.4 = 17.2°C$ DIFF / $17.2 + 78.6 = 95.8°C$ Winding rise 15[illegible]

HOURS	TIME	TEMPERATURE READINGS TOP OIL	BTTM. OIL			AMB. OIL	TEMPERATURE RISE TOP OIL	BTTM. OIL	WATTMETER AND VOLTMETER
Steady									
State 150%		107				28.4	78.6 - 150% Compromise Current		
0		107				28.4	78.6 - began 2 hours at rated I x 150%		
2		106.4				28.3	78.1 - shutdown		

	Compromise I St State	Began 2 hrs at rated I x 150%	Shutdown
Ammeter	9.13	9.00	9.00
Voltmeter	163.2	161	160.7
Wattmeter	830	805	801

LOAD TEST AT C
AMPS
VOLTMETER
WATTMETER

NO LOAD TEST
(T.W.) WATTMETER
(A.W.) VOLTS X AMPS
VA

TIME CONSTANT
63.3 X °C OIL RISE =
TIME CONSTANT =
HRS. MIN.

Al TYPE CONDUCTOR H.V
Al TYPE CONDUCTOR L.V.

CALCULATED COMPROMISE CURRENT 9.13

OTHER REMARKS

TEST REQUESTED BY [illegible] DATE TESTED 3-13-87 BY Bill Belran L.SPEC. # N/A

7 B. BELVAN ATHENS COMPROMISE AMOR. CORE 25KVA 4160V 240 GREG JONES 10 MAR 87 GEN ELECTRIC P217061 050 PCT

0069	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
700	AMB	AMB	AMB	AVER.	61 TOP	RISE										
13:25:00	25.8C	24.9C	25.9C	25.5	26.0C	0.5										
14:25:00	25.9C	25.0C	26.1C	25.6	30.3C	4.7										
15:25:00	26.3C	25.4C	26.5C	26.0	36.2C	10.2										
16:25:00	26.7C	25.8C	26.9C	26.4	41.2C	14.8										
17:25:00	27.1C	26.1C	27.2C	26.8	45.4C	18.6										
18:25:00	27.4C	26.4C	27.5C	27.1	49.0C	21.9										
19:25:00	27.6C	26.6C	27.7C	27.3	51.9C	24.6										
20:25:00	27.9C	26.8C	27.9C	27.5	54.5C	27.0										
21:25:00	28.0C	26.9C	28.1C	27.6	56.6C	29.0										
22:25:00	28.2C	27.0C	28.2C	27.8	58.4C	30.6										
23:25:00	28.3C	27.0C	28.4C	27.9	59.9C	32.0										
00:25:00	28.4C	27.1C	28.5C	28.0	61.5C	33.5										
01:25:00	28.5C	27.1C	28.5C	28.0	62.9C	34.9										
02:25:00	28.6C	27.2C	28.6C	28.1	64.1C	36.0										
03:25:00	28.6C	27.2C	28.7C	28.1	65.1C	37.0										
04:25:00	28.7C	27.2C	28.7C	28.2	65.9C	37.7										
05:25:00	28.7C	27.2C	28.8C	28.2	66.5C	38.3										
06:25:00	28.7C	27.1C	28.8C	28.2	67.0C	38.8										
07:25:00	28.7C	27.1C	28.8C	28.2	67.3C	39.1										
07:32:56	28.7C	27.1C	28.8C	28.2	67.3C	39.1										
08:25:00	28.7C	27.0C	28.8C	28.1	67.4C	39.3										
09:00:00	28.7C	27.0C	28.8C	28.1	67.3C	39.2	← Steady State – begin 2hrs at Rated I (6.00 AMPS)									
10:00:00	28.7C	26.9C	28.8C	28.1	67.0C	38.9										
11:00:00	28.7C	26.9C	28.8C	28.1	66.8C	38.7	← Shut down									

7 B. BELVAN ATHENS COMPROMISE AMOR. CORE 25KVA 4160V 240 GREG JONES 11 MAR 87 GEN ELECTRIC P217061 050 PCT

0070	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
700	AMB	AMB	AMB	AVER.	61 TOP	RISE										
6:45:00	27.8C	26.4C	28.0C	27.4	49.4C	22.0										
0:45:00	28.1C	26.5C	28.2C	27.6	45.3C	17.7										
0:45:00	28.2C	26.7C	28.3C	27.7	43.4C	15.7										
4:45:00	28.5C	26.8C	28.5C	27.9	42.7C	14.8										
7:30:16	28.5C	26.8C	28.5C	27.9	42.4C	14.5										
8:30:00	28.5C	26.7C	28.4C	27.8	42.1C	14.3										
9:30:00	28.4C	26.7C	28.4C	27.8	41.6C	13.8	← Steady State – begin 2hrs. at 30% rated I (7.00 amps)									
0:30:00	28.3C	26.6C	28.3C	27.7	41.1C	13.4	← Shutdown									
1:30:00	27.8C	26.2C	27.7C	27.2	39.7C	12.5										

7 B. BELVAN ATHENS COMPROMISE AMOR. CORE 25KVA 4160V 240 GREG JONES 11 MAR 87 GEN ELECTRIC P217061 050 PCT

7 B. BELVAN ATHENS COMPROMISE AMOR. CORE 25KVA 4160V 240 GREG JONES 11 MAR 87 GEN ELECTRIC P217061 050 PCT

0071	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
00	AMB	AMB	AMB	AVER.	61 TOP	RISE										
2:10:00	27.8C	26.2C	27.8C	27.2	38.7C	11.5										

*** POWER OFF AT 0071:12:13:16, PC = 232C

ATHENS COMPROMISE HAUX. CORE 25KVA 4160V 240 GREG JONES 12 MAR 87 GEN ELECTRIC

0071 700	01 AMB	02 AMB	03 AMB	04 AVER.	05 61 TOP	06 RISE	07	08	09	10	11	12	13	14	15	16
12:16:00	27.8C	26.2C	27.8C	27.2	38.6C	11.4										
12:20:09	27.8C	26.2C	27.8C	27.2	38.5C	11.3										
12:21:00	27.8C	26.2C	27.8C	27.2	38.5C	11.3										
15:21:00	27.9C	26.3C	28.1C	27.4	68.4C	41.0										
18:21:00	28.4C	26.8C	28.5C	27.9	86.6C	58.7										
21:21:00	28.8C	27.1C	28.9C	28.2	95.6C	67.4										
00:21:00	28.8C	27.1C	29.1C	28.3	101.1C	72.8										
03:21:00	29.0C	27.3C	29.3C	28.5	105.4C	76.9										
06:21:00	29.2C	27.4C	29.4C	28.6	107.3C	78.7										
07:25:58	29.1C	27.2C	29.3C	28.5	107.2C	78.7										
07:27:00	29.1C	27.3C	29.4C	28.6	107.2C	78.6										
08:27:00	29.1C	27.2C	29.3C	28.5	107.1C	78.6										
09:09:00	29.0C	27.1C	29.2C	28.4	107.0C	78.6	— begin 2hrs at 150% X rated									
10:09:00	29.0C	27.1C	29.2C	28.4	106.6C	78.2										
11:08:49	28.9C	27.0C	29.2C	28.3	106.4C	78.1	— Shut down									
11:09:00	28.9C	27.0C	29.2C	28.3	106.4C	78.1										

TEMPERATURE TEST RECORD
WESTINGHOUSE FORM 4857K

DTD LAB PAGE № 00736

TRANSFORMER TYPE: Pole TEMPERATURE TEST ON 25 K.V.A. TRANSFORMER STYLE General Electric

CONNECTED H.V. 4160 VOLTS L.V. 120/240 VOLTS

LOAD H.V. 50% 3.00 AMPS. L.V. 52 AMPS. 60 CYCLES

WATTS PER LB. H.V. Cooling curve L.V. MAGNETIZED VOLTS CYCLES ON V

GALLONS OIL CIRCUIT TEST METHOD Compromise NO. OF RADIATORS 0 NO. TUBES 2

REMARKS steel construction

SERIAL # P239216

TIME AFTER SHUTDOWN MIN.	SEC.	TEMP. H.V. WINDING BY RESISTANCE AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.	AVE. WIND. TEMP.	TIME AFTER SHUTDOWN MIN.	SEC.	TEMP. L.V. WINDING BY RESISTANCE AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.	AVE. WIND. TEMP.
		25.5			5.172						25.5			.01555			
1	01				5.650	48.4	0.63	49.03	1	39				.01690	47.24	0.32	47
				by cooling curve –				49.03					by cooling curve –			47.56	

CALC. H.V. WINDING RISE 49.03 – 48.0 = 1.03°C DIFF | 1.03 + 22.6 = 23.63°C HV winding rise

CALC. L.V. WINDING RISE 47.56 – 48 = –.56 DIFF | –.56 + 22.6 = 22.04°C L.V winding rise

HOURS	TIME	TEMPERATURE READINGS TOP OIL	BTTM. OIL			AMB. OIL	TEMPERATURE RISE TOP OIL	BTTM. OIL		WATTMETER AND VOLTMETER
Steady State		51.0	41.3			28.4	22.6	– Compromise Current		
0		51.0	41.0			28.4	22.6	– Began 2 hours at rated I		
2		48.0	39.5			27.8	20.2	– Shutdown		

	Compromise Steady State	Began 2hrs at Rated I	Shutdown
Ammeter	3.861	3.00	3.00
Voltmeter	73.6	58.1	58.0
Wattmeter	163.7	102.0	101.5

LOAD TEST AT 23.5 °C

AMPS 6.00

VOLTMETER 111.6

WATTMETER 366.21

Lab instrument

NO LOAD TEST

(T.W.) WATTMETER 66.33

(A.W.) VOLTS ____ X AMPS ____ = 209.1 VA

TIME CONSTANT

63.3 X ____ °C OIL RISE = ____

TIME CONSTANT = ____ HRS. ____ MIN.

Al TYPE CONDUCTOR H.V.

Al TYPE CONDUCTOR L.V.

CALCULATED COMPROMISE CURRENT 50% = 3.79

OTHER REMARKS

TEST REQUESTED BY Greg Jones DATE TESTED 3-16-87 BY Bill Bel... L.SPEC. # N/A

TEMPERATURE TEST RECORD

WESTINGHOUSE FORM 4857K

DTD LAB PAGE № 00737

TRANSFORMER TYPE: Pole TEMPERATURE TEST ON 25 K.V.A. TRANSFORMER STYLE General Electric

CONNECTED H.V. 4160 VOLTS L.V. 120/240 VOLTS

LOAD H.V. 100% 6.00 AMPS. L.V. AMPS 60 CYCLES

WATTS PER LB. H.V. Cooling Curve L.V. MAGNETIZED VOLTS CYCLES ON V

GALLONS OIL CIRCUIT TEST METHOD Compromise NO. OF RADIATORS NO. TUBES

REMARKS

SERIAL #

TIME AFTER SHUTDOWN MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.	AVE. WIND. TEMP.	TIME AFTER SHUTDOWN MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES	CORRECTION TO SHDN.	AVE. WIND. TEMP.
		25.5			5.172						25.5			.01555			
					6.416	85.70	—	85.7						.01910	82.7	—	8[illegible]

CALC. H.V. WINDING RISE: 85.7 - 78.4 = 7.3°C DIFF / 7.3 + 53.2 = 60.5°C winding rise

CALC. L.V. WINDING RISE: 82.7 - 78.4 = 4.3°C DIFF / 4.3 + 53.2 = 57.5°C winding rise

HOURS	TIME	TOP OIL	BTTM. OIL	AMB. OIL	TOP OIL (RISE)	BTTM. OIL (RISE)	WATTMETER AND VOLTMETER
Steady State		80.4	60.6	27.2	53.2		- Compromise Current
0		80.4	60.6	27.2	53.2		- begin 2 hrs at rated
2		78.4	59.5	27.1	51.3		- Shutdown

	Steady State Compromise I	Begin 2 hours at rated I	Shutdown
Ammeter	6.4	6.00	6.00
Voltmeter	128	120	120
Wattmeter	511.9	452.8 (458) BACK BACK for comparison	447

LOAD TEST AT 25.5 C

AMPS 6.00

VOLTMETER 111.6

WATTMETER 366.2

NO LOAD TEST

(T.W.) WATTMETER 66.33

(A.W.) VOLTS ____ X AMPS ____ =

209.1 VA

TIME CONSTANT

63.3 X ____ °C OIL RISE = ____

TIME CONSTANT = ____ HRS. ____ MIN.

Al TYPE CONDUCTOR H.V.

Al TYPE CONDUCTOR L.V.

CALCULATED COMPROMISE CURRENT 6.44

OTHER REMARKS

TEST REQUESTED BY Greg Jones DATE TESTED 3-18-87 BY Bill Belvan L.SPEC. # —

REPRODUCED AT GOVERNMENT EXPENSE.

TEMPERATURE TEST RECORD

WESTINGHOUSE FORM 4857K

DTD LAB PAGE № 00736

TRANSFORMER TYPE: Pole TEMPERATURE TEST ON 25 K.V.A. TRANSFORMER STYLE General Electric

CONNECTED H.V. 4160 VOLTS L.V. 120/240 VOLTS

LOAD H.V. 150% 9.0 AMPS L.V. AMPS 60 CYCLES

WATTS PER LB. H.V. Cooling Curve L.V. MAGNETIZED VOLTS CYCLES ON V

GALLONS OIL CIRCUIT TEST METHOD Compromise NO. OF RADIATORS NO TUBES

REMARKS

SERIAL #

TIME AFTER SHUTDOWN MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.	AVE. WIND. TEMP.	TIME AFTER SHUTDOWN MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORRECTION TO SHDN.	AVE. WIND. TEMP.
		25.5			5.172						25.5			.01555			
1	11				7.639	144.98	-	144.98	1	54				.02264	139.7	-	13

CALC. H.V. WINDING RISE $144.98 - 128.3 = 16.68°C$ DIFF / $16.68 + 100.8 = 117.48°$ winding rise

CALC. L.V. WINDING RISE $139.7 - 128.3 = 11.4°C$ DIFF / $11.4 + 100.8 = 112.2°C$ winding rise

HOURS	TIME	TEMPERATURE READINGS TOP OIL	BTTM. OIL	AMB. OIL	TEMPERATURE RISE TOP OIL	BTTM. OIL	WATTMETER AND VOLTMETER
Steady State		129.7	95.3	28.9	100.8	Compromise Current	
C		129.7	95.3	28.9	100.8	- begin 2 hrs at rated X150%	
2		128.3	94.8	28.7	99.6	- Shutdown	

	Compromise Steady State	Begin 2 hrs at rated X150%	Shutdown
Ammeter	9.13	9.0	9.0
Voltmeter	199.6	194.5	193
Wattmeter	1267	1202	1187

1200 WATTS comparison from BACK-BACK

LOAD TEST AT C

AMPS

VOLTMETER

WATTMETER

see Page 00737

NO LOAD TEST

(T.W.) WATTMETER

(A.W.) VOLTS X AMPS

VA

TIME CONSTANT

63.3 X °C OIL RISE =

TIME CONSTANT = HRS. MIN

AL TYPE CONDUCTOR H.V.

OL TYPE CONDUCTOR L.V.

CALCULATED COMPROMISE CURRENT

OTHER REMARKS

TEST REQUESTED BY Grey Jones DATE TESTED 3-18-87 BY Bill Belvan L.SPEC. #

7 B. BELVAN ATHENS COMPROMISE STEEL CORE 25KVA 1160V 240 GREG JONES 16 MAR 87 GEN ELECTRIC P239216 50 PCT

0072	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
700	AMB	AMB	AMB	AVER.	16 TOP	RISE	BTM OIL									
15:00:00	27.1C	25.8C	27.2C	26.7	29.2C	2.5	27.3C									
22:00:00	27.5C	26.7C	27.5C	27.2	44.6C	17.4	36.3C									
05:00:00	26.5C	26.0C	26.7C	26.3	47.9C	21.6	38.3C									
12:00:00	25.7C	25.1C	26.0C	25.6	48.3C	22.7	38.5C									
19:00:00	27.6C	26.8C	27.6C	27.3	50.2C	22.9	40.7C									
02:00:00	27.6C	26.8C	27.4C	27.2	50.2C	23.0	40.3C									
09:00:00	26.1C	25.4C	26.2C	25.9	48.9C	23.0	38.9C									
16:00:00	26.8C	26.1C	26.8C	26.5	49.5C	23.0	39.9C									
23:00:00	28.2C	27.3C	27.9C	27.8	50.6C	22.8	40.7C									
06:00:00	28.8C	27.7C	28.6C	28.3	51.2C	22.9	41.5C									
07:30:00	28.9C	27.7C	28.7C	28.4	51.3C	22.9	41.6C	—								
08:30:00	29.0C	27.6C	28.6C	28.4	51.0C	22.6	41.3C	— St. state - begin 2hRS at 50% Rated								
09:30:00	28.6C	27.4C	28.2C	28.0	49.6C	21.6	40.4C									
10:30:00	28.4C	27.2C	28.0C	27.8	48.1C	20.3	39.6C									
10:34:00	28.4C	27.2C	28.0C	27.8	48.0C	20.2	39.5C	~ Shutdown								
10:35:00	28.4C	27.2C	28.0C	27.8	47.9C	20.1	39.4C									
10:36:00	28.4C	27.2C	28.0C	27.8	47.9C	20.1	39.4C									
10:37:00	28.4C	27.2C	28.0C	27.8	47.8C	20.0	39.4C									
10:38:00	28.4C	27.2C	28.0C	27.8	47.9C	20.1	39.4C									
10:39:00	28.4C	27.2C	28.0C	27.8	47.9C	20.1	39.4C									
10:40:00	28.4C	27.2C	28.0C	27.8	47.8C	20.0	39.4C									
10:41:00	28.4C	27.2C	28.0C	27.8	47.8C	20.0	39.4C									
10:42:00	28.4C	27.2C	27.9C	27.8	47.8C	20.0	39.3C									

U. BELVAH AIKENS COMPROMISE STEEL CORE 25KVA 41600 240 GREG JONES 16 MAR 87 GEN ELECTRIC

C076	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
700	AMB	AMB	AMB	AVER.	16 TOP	RISE	BTM OIL									
15:15:00	26.6C	25.5C	26.7C	26.2	48.4C	22.2	39.3C									
17:15:00	27.2C	26.2C	27.4C	26.9	82.1C	55.2	54.5C									
19:15:00	28.0C	27.0C	28.2C	27.7	101.6C	73.8	70.8C									
21:15:00	28.5C	27.4C	28.8C	28.2	112.1C	83.9	80.5C									
23:15:00	28.9C	27.7C	29.2C	28.6	117.6C	89.0	85.7C									
01:15:00	29.2C	28.0C	29.6C	28.9	122.4C	93.5	89.5C									
03:15:00	29.6C	28.2C	29.9C	29.2	125.2C	96.0	92.0C									
05:15:00	29.9C	28.4C	30.2C	29.5	126.6C	97.1	93.4C									
07:15:00	30.1C	28.6C	30.4C	29.7	126.7C	97.0	93.7C									
07:22:56	30.1C	28.6C	30.4C	29.7	126.7C	97.0	93.7C									
08:11:00	29.9C	28.5C	30.1C	29.5	128.9C*	99.4	94.2C									
09:11:00	29.5C	28.2C	29.7C	29.1	129.3C*	100.2	94.5C									
10:11:00	29.3C	28.1C	29.5C	28.9	129.6C*	100.7	95.1C									
10:52:00	29.2C	28.0C	29.5C	28.9	129.7C*	100.8	95.3C	— St. State – began 2 hrs at 150% rated								
11:52:00	29.1C	27.9C	29.4C	28.7	129.1C*	100.4	95.3C									
12:52:00	29.1C	27.9C	29.3C	28.7	128.3C*	99.6	94.8C									
12:53:00	29.1C	27.9C	29.3C	28.7	128.3C*	99.6	94.8C	— Shut down 111.55 meas								
12:54:00	29.1C	27.8C	29.3C	28.7	128.3C*	99.6	94.8C									
12:55:00	29.1C	27.9C	29.3C	28.7	128.2C*	99.5	94.7C									
12:56:00	29.1C	27.9C	29.3C	28.7	128.1C*	99.4	94.6C									
12:57:00	29.1C	27.9C	29.3C	28.7	128.0C*	99.3	94.6C									
12:58:00	29.1C	27.9C	29.3C	28.7	127.9C*	99.2	94.5C	— ~~Shutdo~~ 111.2								
12:59:00	29.1C	27.9C	29.3C	28.7	127.7C*	99.0	94.5C									

[illegible] COMPROMISE [illegible] 240 GREG JONES 17 MAR 87 [illegible]

0076	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
700	AMB	AMB	AMB	AVER.	16 TOP	RISE	BTM OIL									
07:46:00	27.4C	26.6C	27.6C	27.2	80.4C	53.2	60.8C									
08:35:00	27.4C	26.6C	27.6C	27.2	80.4C	53.2	60.6C									
09:35:00	27.4C	26.5C	27.5C	27.1	79.3C	52.2	60.2C									
10:35:00	27.5C	26.4C	27.5C	27.1	78.5C	51.4	59.6C									
10:38:00	27.4C	26.4C	27.5C	27.1	78.4C	51.3	59.5C									
10:39:00	27.4C	26.4C	27.4C	27.0	78.4C	51.4	59.4C									
10:40:00	27.4C	26.4C	27.5C	27.1	78.3C	51.2	59.4C									
10:41:00	27.4C	26.4C	27.5C	27.1	78.3C	51.2	59.4C									
10:42:00	27.4C	26.4C	27.5C	27.1	78.2C	51.1	59.3C									
10:43:00	27.4C	26.4C	27.5C	27.1	78.1C	51.0	59.3C									
10:44:00	27.4C	26.4C	27.5C	27.1	78.1C	51.0	59.3C									
10:45:00	27.4C	26.4C	27.5C	27.1	78.0C	50.9	59.2C									

— begin 2 hrs at Rated

TABLE A.11.1 NO-LOAD LOSS SATURATION DATA.

FOR TOP OIL TEMPERATURE STABILIZED AT [illegible] WITH NO [illegible].
AMORPHOUS METAL TRANSFORMER P217061-YZA.

FLUX VOLTS	% RATED FLUX VOLTS	RMS VOLTS	CURRENT	% CURRENT	WATTS
20.0	16.7	20.4	0.060	0.005	1.1
40.0	33.3	40.2	0.079	0.01	3.[illegible]
60.0	50.0	60.1	0.096	0.02	5.[illegible]
80.0	66.7	80.0	0.113	0.04	8.4
90.0	75.0	90.0	0.127	0.05	10.3
100.0	83.3	100.1	0.153	0.06	12.5
110.0	91.7	110.0	0.210	0.09	15.0
120.0	100.0	120.0	0.378	0.18	18.7
125.0	104.2	125.1	0.571	0.29	20.7
130.0	108.3	130.1	0.957	0.50	22.9
135.0	112.5	133.0	1.848	1.00	25.4

TABLE A.11.2 NO-LOAD LOSS SATURATION DATA.

FOR TOP OIL TEMPERATURE STABILIZED AT 41C AFTER LOADING
AT 50% OF NAMEPLATE RATING.
AMORPHOUS METAL TRANSFORMER P217061-YZA.

FLUX VOLTS	% RATED FLUX VOLTS	RMS VOLTS	CURRENT	% CURRENT	WATTS
20.0	16.7	20.5	0.068	0.006	1.[illegible]
40.0	33.3	40.2	0.090	0.01	3.1
60.0	50.0	60.2	0.094	0.02	5.7
80.0	66.7	80.0	0.110	0.04	8.[illegible]
90.0	75.0	90.1	0.126	0.05	10.0
100.0	83.3	100.0	0.152	0.06	12.7
110.0	91.7	110.0	0.217	0.10	14.9
120.0	100.0	120.1	0.404	0.19	19.4
125.0	104.2	125.0	0.636	0.32	20.7
130.0	108.3	129.9	1.111	0.58	22.5
135.0	112.5	135.1	2.418	1.31	25.7

TABLE A.11.3 NO-LOAD LOSS SATURATION DATA.

FOR TOP OIL TEMPERATURE STABILIZED AT [illegible] AFTER LOADING
AT 100% OF NAMEPLATE RATING.
AMORPHOUS METAL TRANSFORMER P217061-YZA.

FLUX VOLTS	% RATED FLUX VOLTS	RMS VOLTS	CURRENT	% CURRENT	WATTS
20.0	16.7	20.4	0.063	0.005	1.7
40.0	33.3	40.1	0.075	0.01	2.9
60.0	50.0	60.2	0.089	0.02	5.1
80.0	66.7	80.1	0.107	0.03	7.7
90.0	75.0	90.1	0.123	0.04	9.7
100.0	83.3	100.0	0.152	0.06	11.9
110.0	91.7	110.1	0.228	0.10	14.6
120.0	100.0	119.9	0.468	0.22	18.0
125.0	104.2	125.1	0.773	0.39	19.9
130.0	108.3	130.1	1.459	0.76	22.1
135.0	112.5	135.6	4.785	2.60	26.7

TABLE A.11.4 NO-LOAD LOSS SATURATION DATA.

FOR TOP OIL TEMPERATURE STABILIZED AT 106C AFTER LOADING
AT 150% OF NAMEPLATE RATING.
AMORPHOUS METAL TRANSFORMER P217061-YZA

FLUX VOLTS	% RATED FLUX VOLTS	RMS VOLTS	CURRENT	% CURRENT	WATTS
20.0	16.7	20.3	0.061	0.005	1.1
40.0	33.3	40.2	0.074	0.01	2.9
60.0	50.0	60.0	0.086	0.02	4.9
80.0	66.7	80.1	0.104	0.03	7.7
90.0	75.0	90.0	0.124	0.04	9.5
100.0	83.3	100.1	0.160	0.06	11.7
110.0	91.7	109.8	0.268	0.12	14.4
120.0	100.0	120.0	0.654	0.31	17.7
125.0	104.2	125.0	1.218	0.61	19.7
130.0	108.3	130.2	3.537	1.84	[illegible]
135.0	112.5	139.6	8.956	5.00	[illegible].9 *

* CORRECTED ACCORDING TO ANSI C57.12.90 - 1980 SEC. [illegible]

TABLE A.11.5 NO-LOAD LOSS SATURATION DATA.

FOR TOP OIL TEMPERATURE STABILIZED AT 22.7C WITH NO-LOAD.
STANDARD SILICON STEEL TRANSFORMER P239216-YOB.

FLUX VOLTS	% RATED FLUX VOLTS	RMS VOLTS	CURRENT	% CURRENT	WATTS
20.0	16.7	20.4	0.197	0.016	2.9
40.0	33.3	40.1	0.242	0.04	7.[illegible]
60.0	50.0	60.0	0.299	0.07	15.3
80.0	66.7	80.0	0.361	0.12	25.5
90.0	75.0	90.1	0.402	0.14	31.9
100.0	83.3	99.9	0.463	0.19	39.5
110.0	91.7	109.9	0.618	0.27	49.7
120.0	100.0	120.0	1.829	0.88	68.9
125.0	104.2	125.2	4.447	2.23	92.6
130.0	108.3	131.0	7.611	3.99	138.6
132.0	110.0	133.9	8.537	4.57	163.2 *

TABLE A.11.6 NO-LOAD LOSS SATURATION DATA.

FOR TOP OIL TEMPERATURE STABILIZED AT 47.8C AFTER LOADING
AT 50% OF NAMEPLATE RATING.
STANDARD SILICON STEEL TRANSFORMER P239216-YOB.

FLUX VOLTS	% RATED FLUX VOLTS	RMS VOLTS	CURRENT	% CURRENT	WATTS
20.0	16.7	20.3	0.179	0.015	2.6
40.0	33.3	40.3	0.243	0.04	7.8
60.0	50.0	60.2	0.300	0.07	15.2
80.0	66.7	80.0	0.358	0.11	24.9
90.0	75.0	90.1	0.399	0.14	31.0
100.0	83.3	100.0	0.458	0.18	38.4
110.0	91.7	110.1	0.623	0.27	48.8
120.0	100.0	120.1	1.979	0.95	68.5
125.0	104.2	125.3	4.850	2.43	93.2
130.0	108.3	131.1	7.785	4.08	139.1
132.0	110.0	134.7	8.892	4.79	166.6 *

* CORRECTED ACCORDING TO ANSI C57.12.90 - 1980 SEC. 8.2.1

TABLE A.11.7 NO-LOAD LOSS SATURATION DATA.

FOR TOP OIL TEMPERATURE STABILIZED AT 78C AFTER LOADING AT 100% OF NAMEPLATE RATING.
STANDARD SILICON STEEL TRANSFORMER P239216-YOB.

FLUX VOLTS	% RATED FLUX VOLTS	RMS VOLTS	CURRENT	% CURRENT	WATTS
20.0	16.7	20.4	0.172	0.014	2.5
40.0	33.3	40.2	0.230	0.04	7.4
60.0	50.0	60.2	0.289	0.07	14.6
80.0	66.7	80.2	0.350	0.11	24.2
90.0	75.0	89.9	0.392	0.14	30.3
100.0	83.3	100.0	0.453	0.19	37.7
110.0	91.7	110.1	0.629	0.28	47.7
120.0	100.0	120.1	2.096	1.01	67.3
125.0	104.2	125.1	5.280	2.64	93.4
130.0	108.3	130.8	7.900	4.13	143.0
132.0	110.0	134.3	9.028	4.65	175.6 *

TABLE A.11.8 NO-LOAD LOSS SATURATION DATA.

FOR TOP OIL TEMPERATURE STABILIZED AT 128C AFTER LOADING AT 150% OF NAMEPLATE RATING.
STANDARD SILICON STEEL TRANSFORMER P239216-YOB

FLUX VOLTS	% RATED FLUX VOLTS	RMS VOLTS	CURRENT	% CURRENT	WATTS
20.0	16.7	20.3	0.156	0.013	2.2
40.0	33.3	40.1	0.218	0.03	6.9
60.0	50.0	60.1	0.277	0.07	13.9
80.0	66.7	80.1	0.340	0.11	23.5
90.0	75.0	90.1	0.382	0.14	29.5
100.0	83.3	100.0	0.450	0.19	36.7
110.0	91.7	110.0	0.649	0.29	46.5
120.0	100.0	120.1	2.494	1.20	65.8
125.0	104.2	125.2	6.325	3.17	94.5
130.0	108.3	131.3	8.514	4.47	150.2
131.2	109.3	134.7	9.479	5.11	174.5 *

* CORRECTED ACCORDING TO ANSI C57.12.90 - 1980 SEC. 9.3.

FIGURE A.11.1

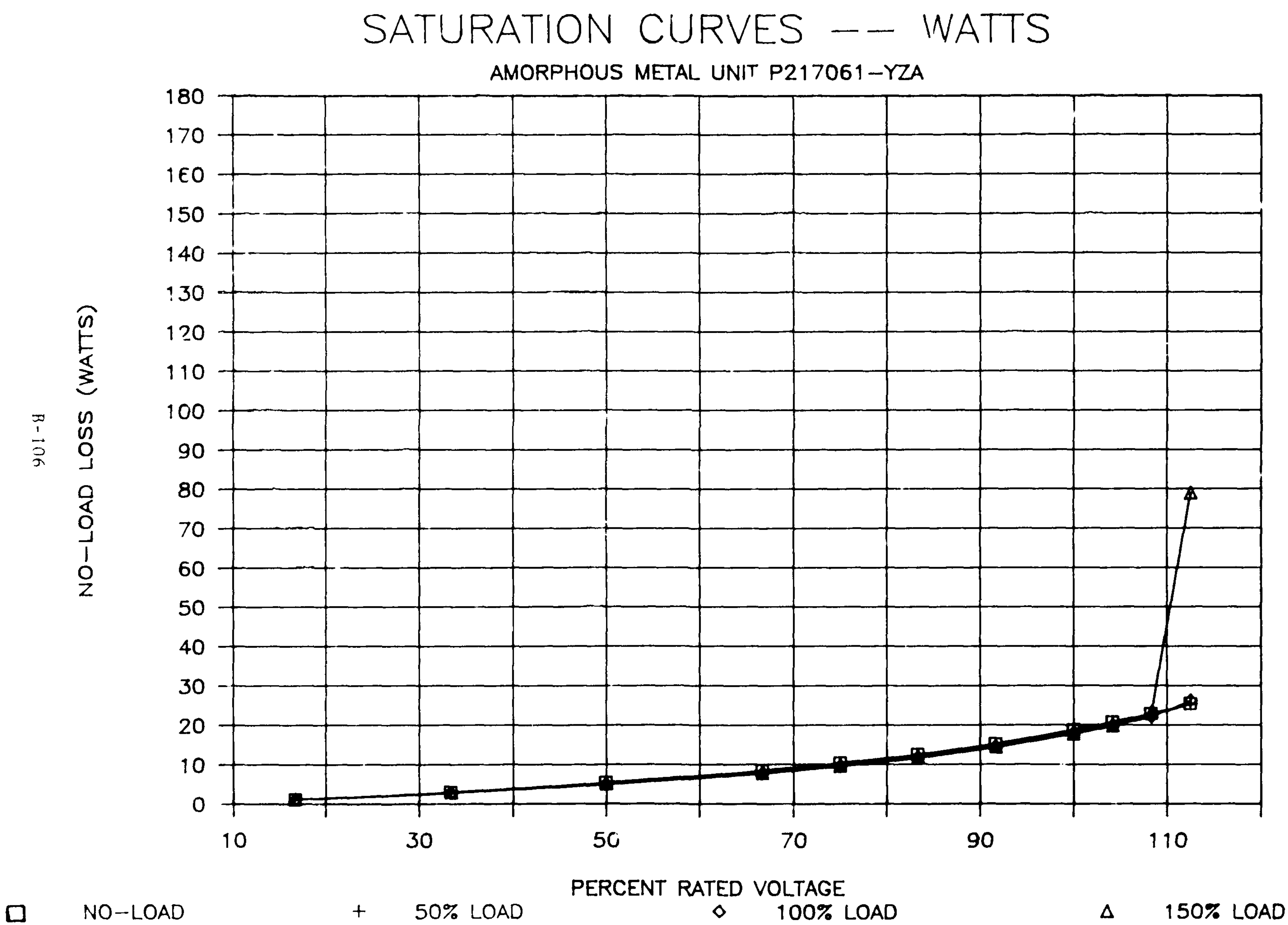

SATURATION CURVES -- WATTS
AMORPHOUS METAL UNIT P217061-YZA
NO-LOAD LOSS (WATTS)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
10
30
50
70
90
110
PERCENT RATED VOLTAGE
NO-LOAD
50% LOAD
100% LOAD
150% LOAD

FIGURE A.11.2

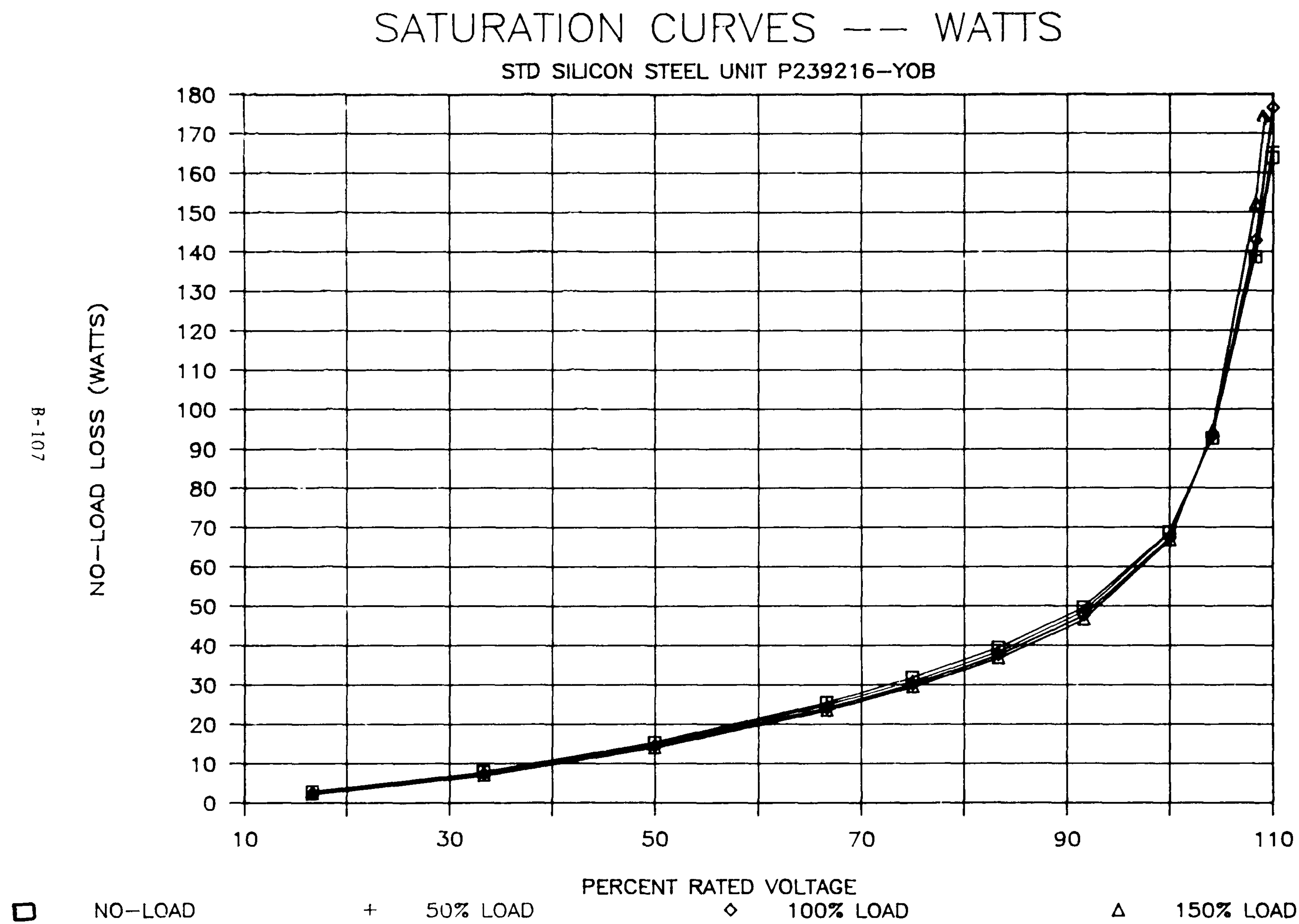

SATURATION CURVES -- WATTS
STD SILICON STEEL UNIT P239216-YOB
NO-LOAD LOSS (WATTS)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
10
30
50
70
90
110
PERCENT RATED VOLTAGE
NO-LOAD
+ 50% LOAD
◇ 100% LOAD
Δ 150% LOAD

FIGURE A.11.3

SATURATION CURVES -- % EXCITING CURRENT

AMORPHOUS METAL UNIT P217061-YZA

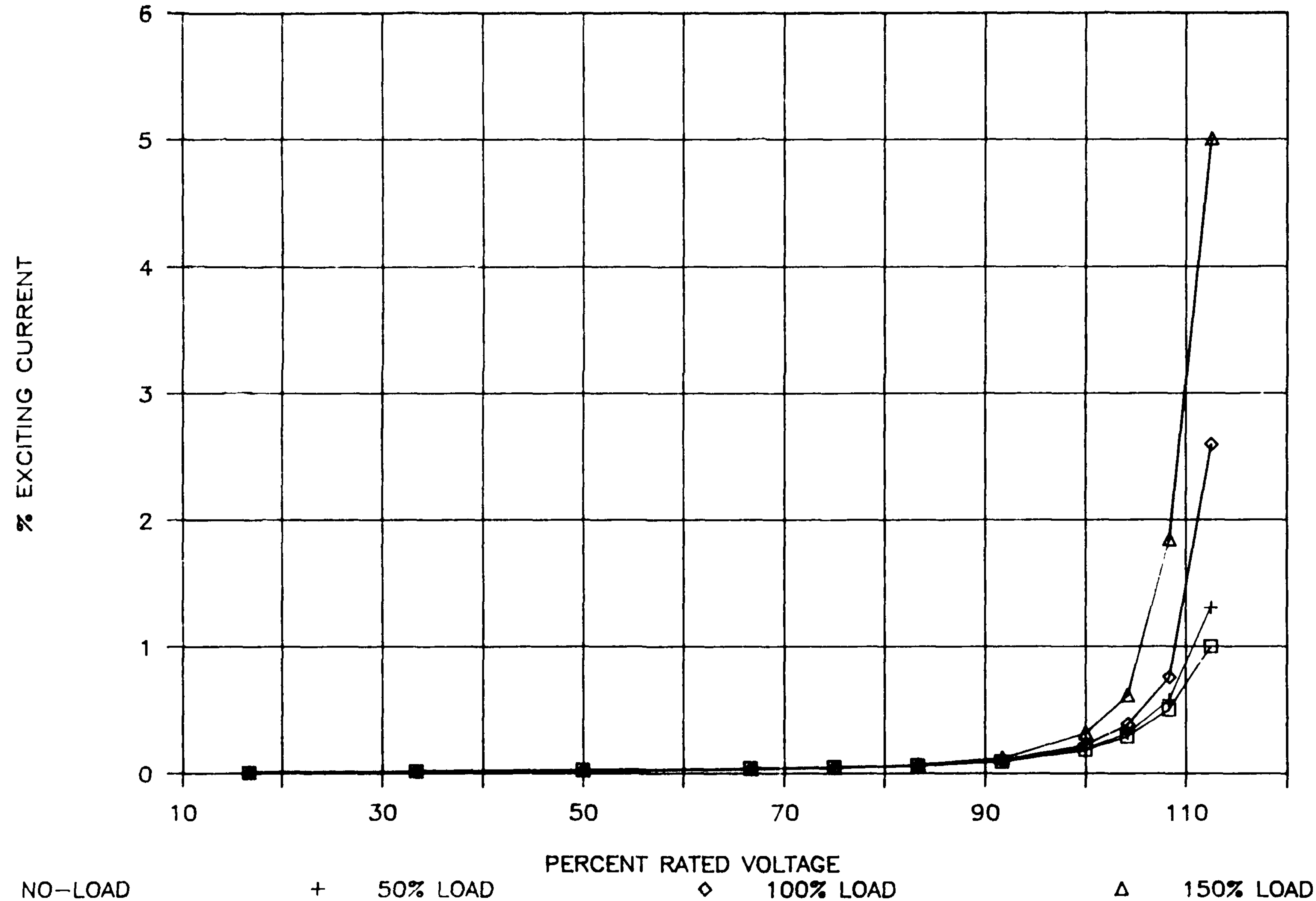
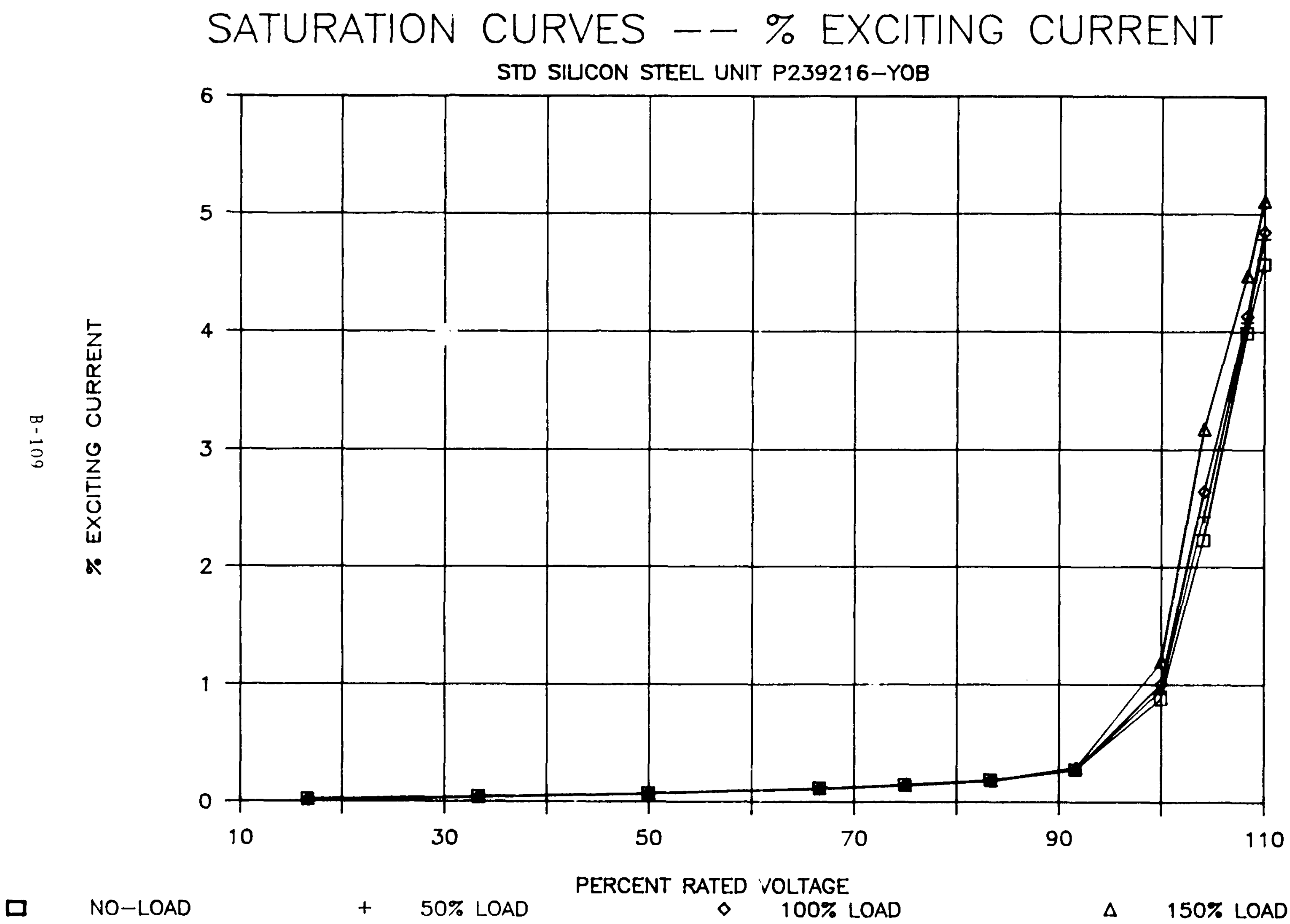


FIGURE A.11.4



SATURATION CURVES -- % EXCITING CURRENT
STD SILICON STEEL UNIT P239216-YOB
% EXCITING CURRENT
0
1
2
3
4
5
6
10
30
50
70
90
110
PERCENT RATED VOLTAGE
NO-LOAD
+ 50% LOAD
◇ 100% LOAD
Δ 150% LOAD

TABLE A.11.9 PERCENT REGULATION - MEASURED & CALCULATED VALUES
FOR [illegible] METAL TRANSFORMER [illegible]

% LOAD	LOAD LOSS (WATTS)	% RESISTANCE	% REACTANCE	* MEASURED VALUES * (SEE NOTE) % REGULATION PF = 1	% REGULATION PF = .8 LAG	CALCULATED FROM COMMERCIAL TEST REPORT (APPENDIX A.11) % REGULATION PF = 1	% REGULATION PF = .8 LAG
50	69.5	0.28	2.17	0.70	1.51		
100	[illegible]	1.05	[illegible]	1.07	2.08	1.01	[illegible]
150	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		

TABLE A.11.10 PERCENT REGULATION - MEASURED & CALCULATED VALUES
FOR STANDARD SILICON STEEL TRANSFORMER [illegible]

% LOAD	LOAD LOSS (WATTS)	% RESISTANCE	% REACTANCE	* MEASURED VALUES * (SEE NOTE) % REGULATION PF = 1	% REGULATION PF = .8 LAG	CALCULATED FROM COMMERCIAL TEST REPORT (APPENDIX A.11) % REGULATION PF = 1	% REGULATION PF = .8 LAG
50	102.[illegible]	1.4[illegible]	2.27	0.47	1.66		
100	451.8	1.81	2.27	1.84	2.79	1.83	2.75
150	1010.[illegible]	4.81	2.27	4.87	5.19		

NOTE: % REGULATION IS CALCULATED PER ANSI C57.12.90 SEC 14.4.1.1.
* MEASURED VALUES * OF % REGULATION ARE CALCULATED USING THE FIRST FOUR COLUMNS OF DATA. % LOAD, LOAD LOSS, & % RESISTANCE VALUES ARE FROM TEMPERATURE RISE TESTS (SEE THIS APPENDIX). % REACTANCE VALUES ARE FROM THE COMMERCIAL TEST REPORT (SEE THIS APPENDIX). REACTANCE IS ASSUMED CONSTANT WITH CHANGING LOAD/TEMPERATURE.

Figure A.11.5

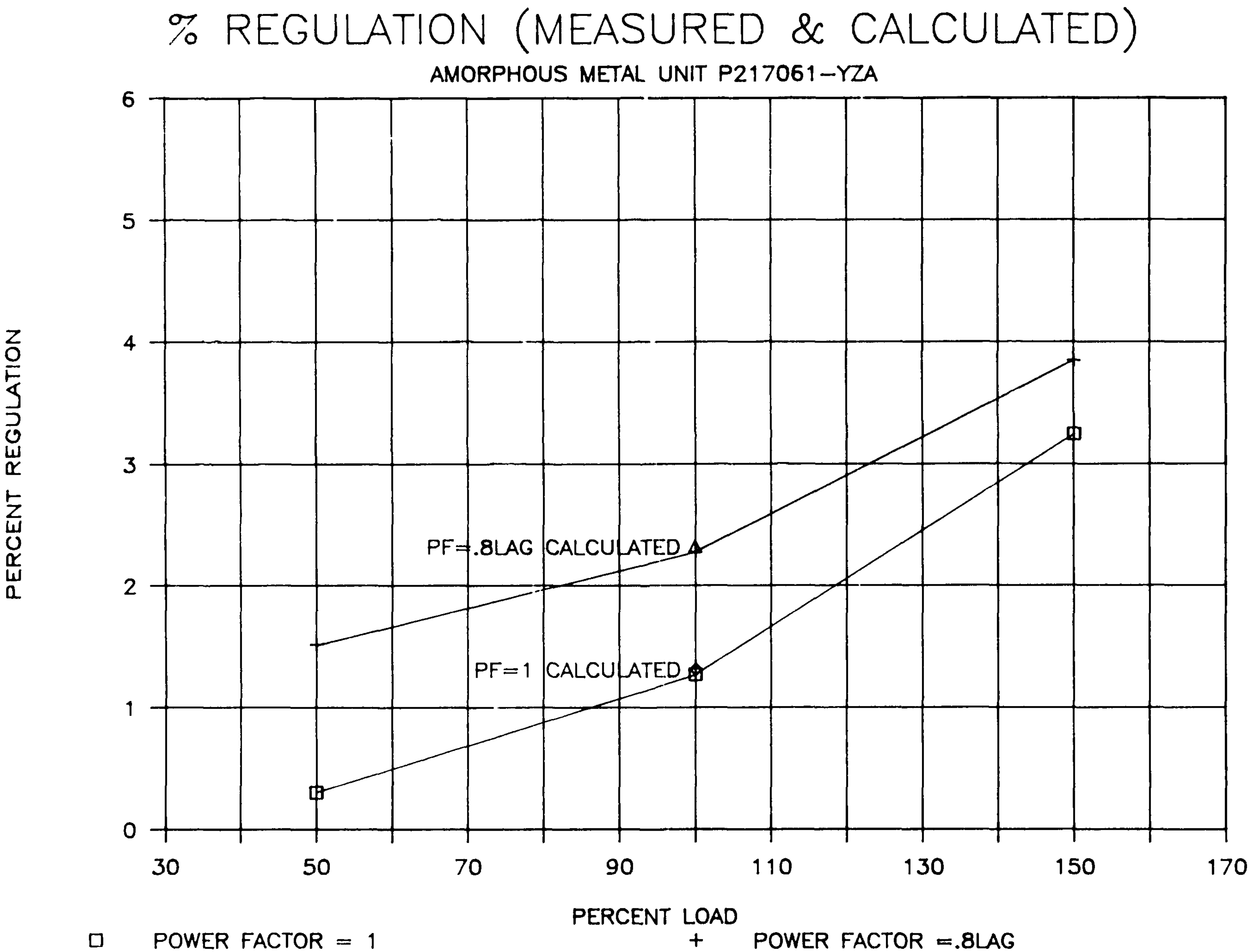

% REGULATION (MEASURED & CALCULATED)
AMORPHOUS METAL UNIT P217061-YZA
PERCENT REGULATION
0
1
2
3
4
5
6
PF=.8LAG CALCULATED
PF=1 CALCULATED
30
50
70
90
110
130
150
170
PERCENT LOAD
□ POWER FACTOR = 1
+ POWER FACTOR =.8LAG

FIGURE A.11.6

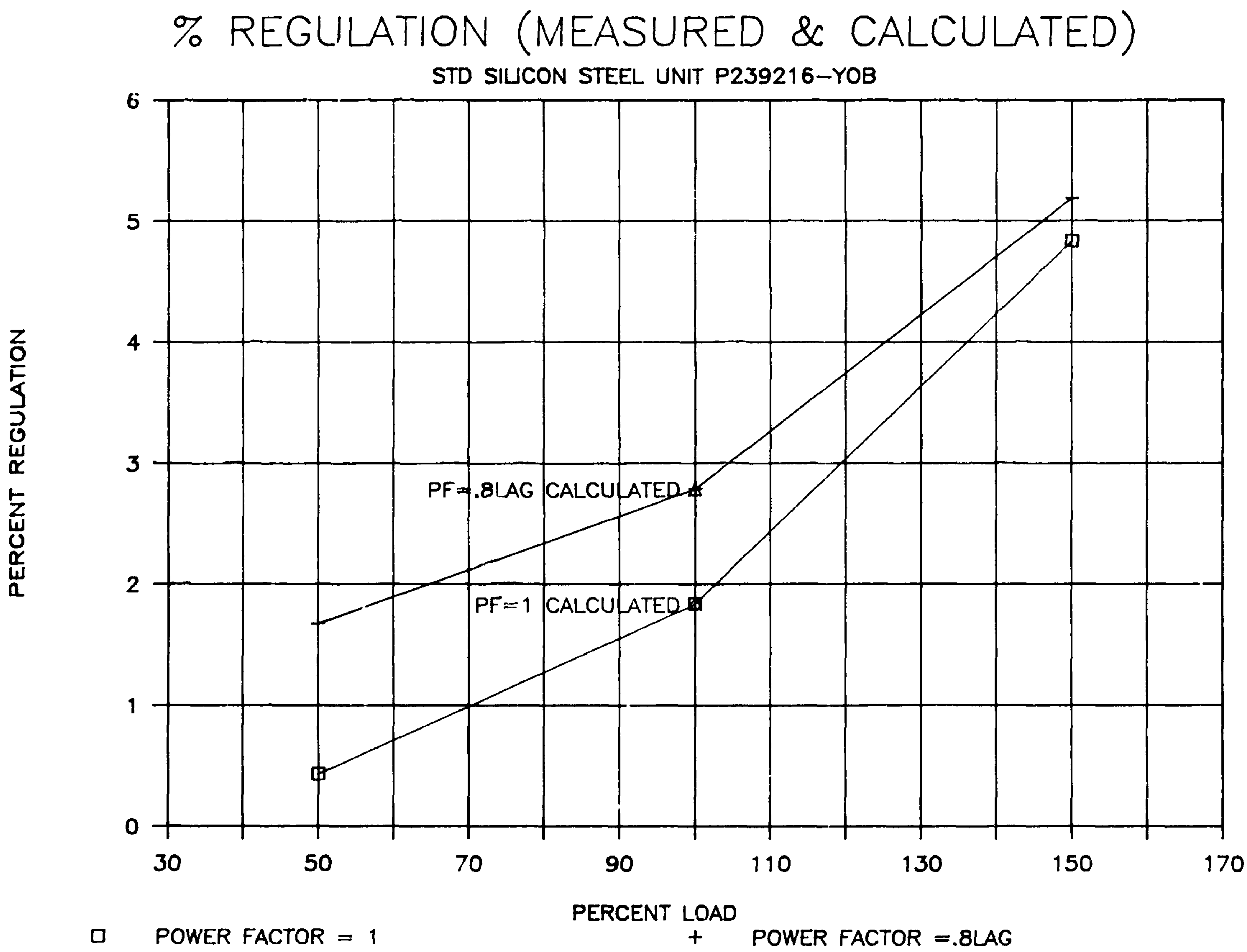

% REGULATION (MEASURED & CALCULATED)
STD SILICON STEEL UNIT P239216-YOB
PERCENT REGULATION
0
1
2
3
4
5
6
PF=.8LAG CALCULATED
PF=1 CALCULATED
30
50
70
90
110
130
150
170
PERCENT LOAD
POWER FACTOR = 1
+ POWER FACTOR =.8LAG

TABLE A.11.11 PERCENT EFFICIENCY - MEASURED & CALCULATED VALUES
FOR AMORPHOUS METAL TRANSFORMER P217061-YZA

			" MEASURED VALUES " (SEE NOTE)		CALCULATED FROM COMMERCIAL TEST REPORT (APPENDIX A.11)	
% LOAD	LOAD LOSS (WATTS)	% NO-LOAD LOSS (WATTS)	% EFFICIENCY PF = 1	% EFFICIENCY PF = .8 LAG	% EFFICIENCY PF = 1	% EFFICIENCY PF = .8 LAG
50	69.5	18.4	99.65	99.56		
100	311.4	18.0	98.70	98.38	98.7	98.3
150	805.0	17.7	96.88	96.13		

TABLE A.11.12 PERCENT EFFICIENCY - MEASURED & CALCULATED VALUES
FOR STANDARD SILICON STEEL TRANSFORMER P239216-Y0B

			" MEASURED VALUES " (SEE NOTE)		CALCULATED FROM COMMERCIAL TEST REPORT (APPENDIX A.11)	
% LOAD	LOAD LOSS (WATTS)	% NO-LOAD LOSS (WATTS)	% EFFICIENCY PF = 1	% EFFICIENCY PF = .8 LAG	% EFFICIENCY PF = 1	% EFFICIENCY PF = .8 LAG
50	102.0	68.5	99.32	99.15		
100	452.8	67.3	97.96	97.47	98.00	97.50
150	1202.0	66.8	95.17	94.03		

NOTE: % EFFICIENCY IS CALCULATED PER ANSI C57.12.90 SEC 14.3.
" MEASURED VALUES " OF % EFFICIENCY ARE CALCULATED USING THE FIRST THREE COLUMNS OF DATA. % LOAD AND LOAD LOSS VALUES ARE FROM TEMPERATURE RISE TESTS (SEE THIS APPENDIX). NO-LOAD LOSS VALUES ARE FROM THE SATURATION CURVES (SEE TABLES A.11.1 THRU A.11.8).

FIGURE A.11.7

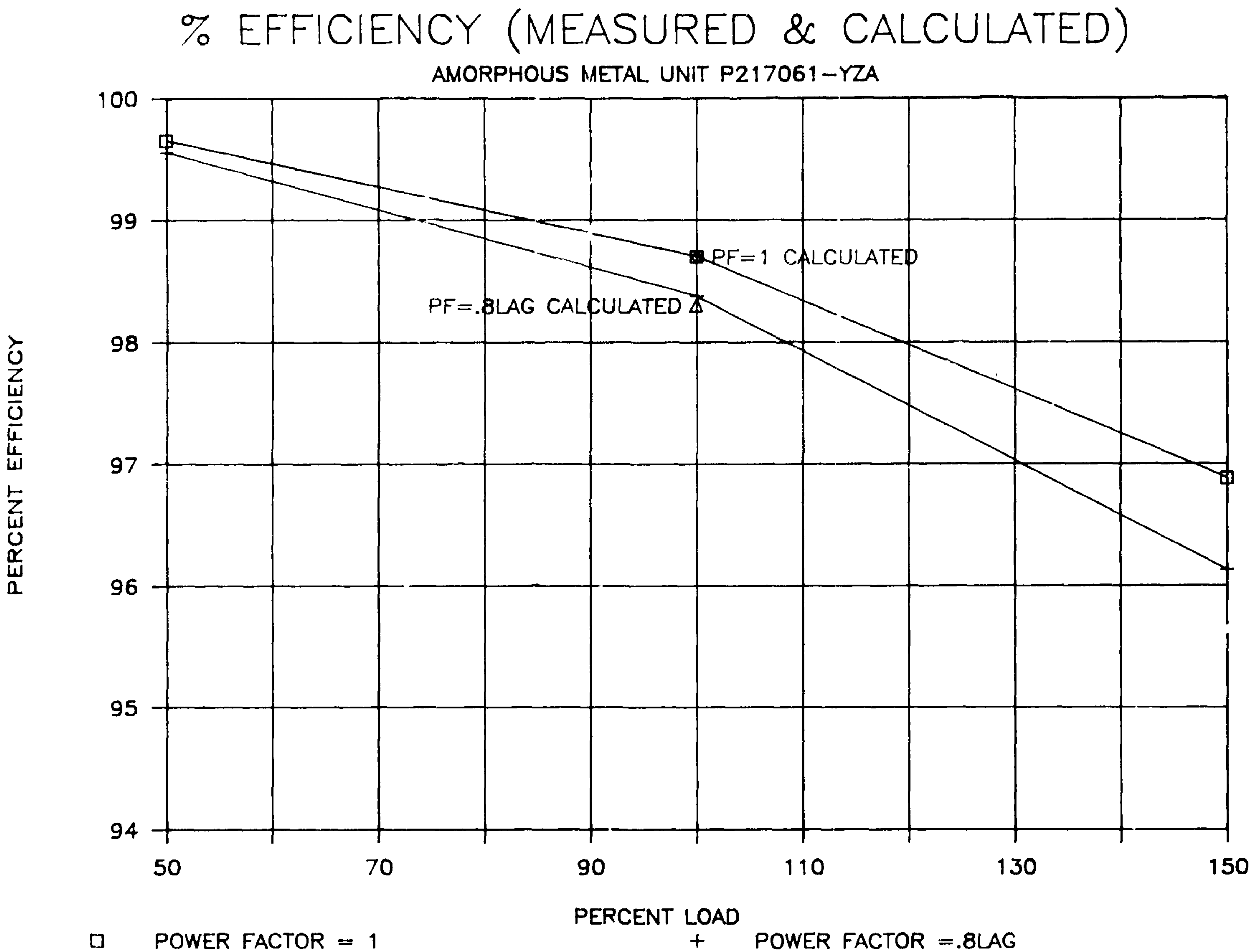
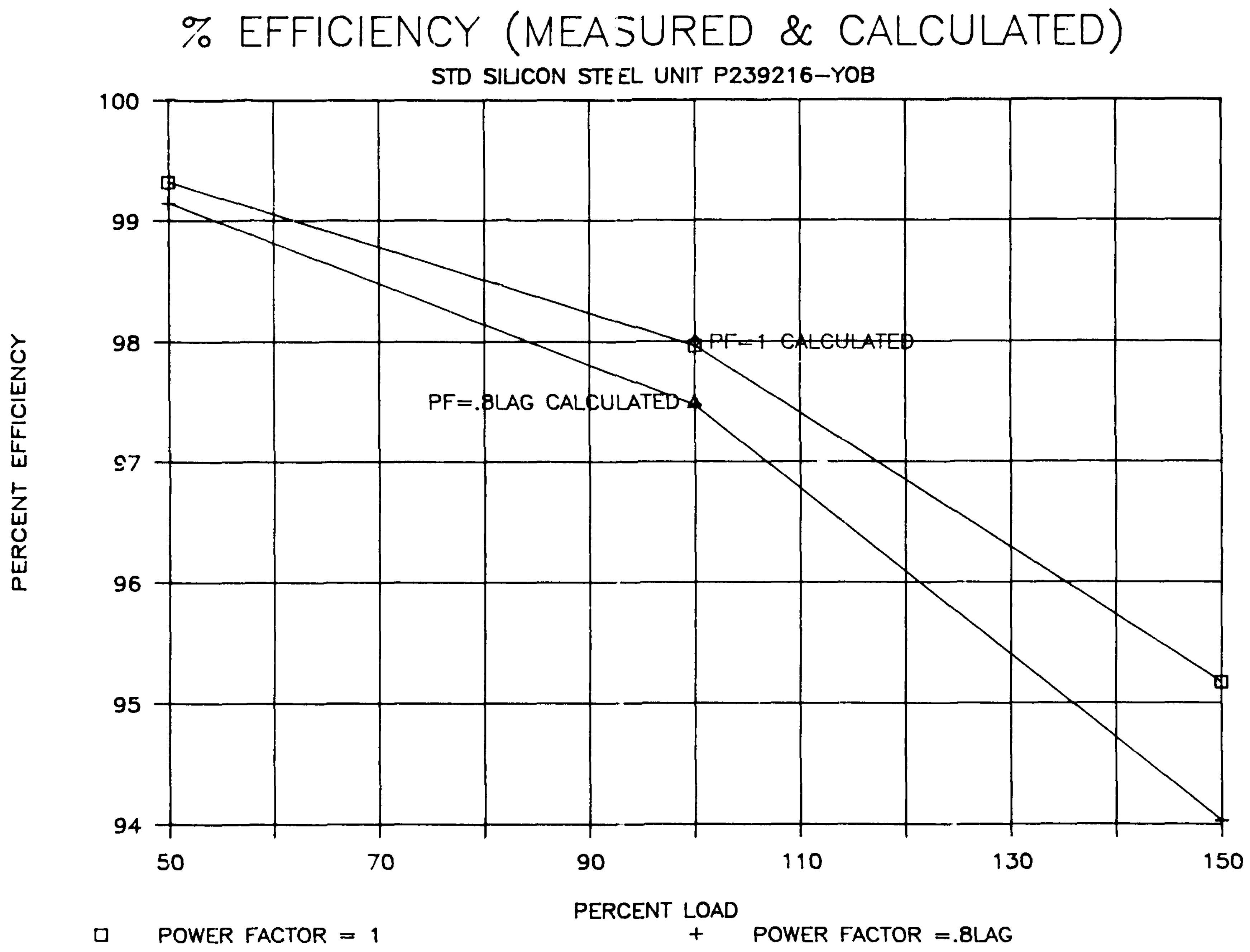

% EFFICIENCY (MEASURED & CALCULATED)
AMORPHOUS METAL UNIT P217061–YZA
PERCENT EFFICIENCY
100
99
98
97
96
95
94
50
70
90
110
130
150
PERCENT LOAD
PF=1 CALCULATED
PF=.8LAG CALCULATED
□ POWER FACTOR = 1
+ POWER FACTOR =.8LAG

FIGURE A.11.8


% EFFICIENCY (MEASURED & CALCULATED)
STD SILICON STEEL UNIT P239216-YOB
PERCENT EFFICIENCY
100
99
98
97
96
95
94
PF=1 CALCULATED
PF=.8LAG CALCULATED
50
70
90
110
130
150
PERCENT LOAD
POWER FACTOR = 1
POWER FACTOR =.8LAG

WESTINGHOUSE DTD COMMERCIAL TEST REPORT

DATE:03/20/97

CONDITION: FOLLOWING SATURATION CURVES

STYLE: G.E. 25kVA STANDARD SILICON STEEL POLE TYPE

LV: 120/240 HV: 4160: 75kV BIL SERIAL #:P239216-Y0B

RATIO	PASS	* HV RESISTANCE (OHMS)	6.342
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01924
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	437.9
APPLIED POTENTIAL - HLIC	PASS	* STRAYS	13.1
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	451.0
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	519.0
NL LOSS (WATTS)	67	* % RESISTANCE	1.80
% EXCITING CURRENT	0.82	* % REACTANCE	2.23
% EFFICIENCY @ PF=1	98.0	* % IMPEDANCE	2.87
% EFFICIENCY @ PF=.8	97.5	% REGULATION @ PF=1	1.83
		% REGULATION @ PF=.8	2.78

TEST ENGINEER: Gregg V. Jones

GREGG V. JONES

* CORRECTED TO 85 DEGREES C

WESTINGHOUSE DTD COMMERCIAL TEST REPORT   DATE: 10/20/87

CONDITION: FOLLOWING SATURATION CURVES

STYLE: G.E. 25kVA AMORPHOUS METAL POLE TYPE

LV: 120/240   HV: 4160Y   75KV BIL   SERIAL #:PC17061-Y2A

RATIO	PASS	* HV RESISTANCE (OHMS)	4.683
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01324
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	312.8
APPLIED POTENTIAL - HLIC	PASS	* STRAYS	10.2
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	323.0
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	340.1
NL LOSS (WATTS)	17.1	* % RESISTANCE	1.29
% EXCITING CURRENT	0.17	* % REACTANCE	[illegible]
% EFFICIENCY @ PF=1	98.7	* % IMPEDANCE	[illegible]
% EFFICIENCY @ PF=.9	98.7	% REGULATION @ PF=1	1.31
		% REGULATION @ PF=.8	[illegible]

TEST ENGINEER: Gregg V. Jones
GREGG V. JONES

* CORRECTED TO 85 DEGREES C

Appendix C

PHOTOGRAPHS OF AMORPHOUS METAL-CORE TRANSFORMER TESTING

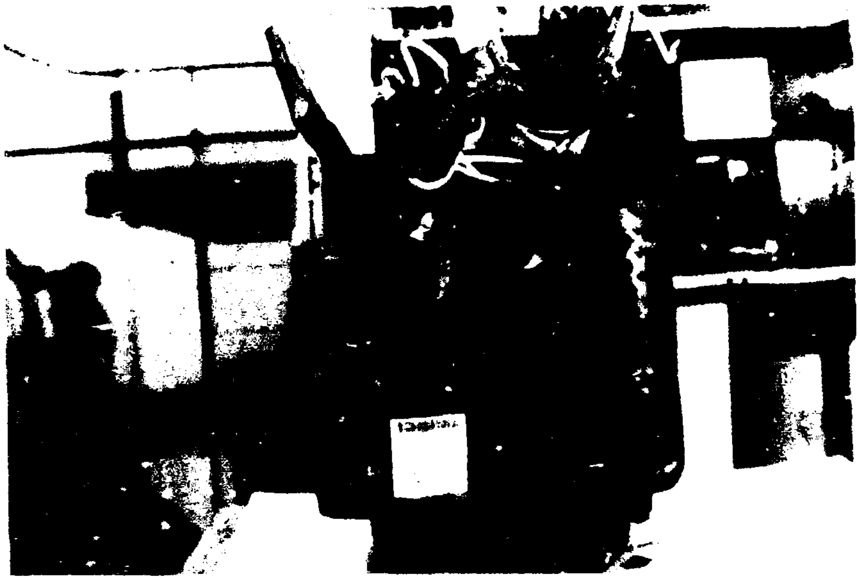


Figure C-1. 25-kVA amorphous metal-core transformer windings and core.

Figure C-2. A 25-kVA amorphous metal-core transformer on the left. A 25-kVA silicon-steel transformer on the right. Note that the amorphous metal-core transformer is larger.

Figure C-3. 25-kVA amorphous metal-core transformers undergoing commercial tests at transformer plant.

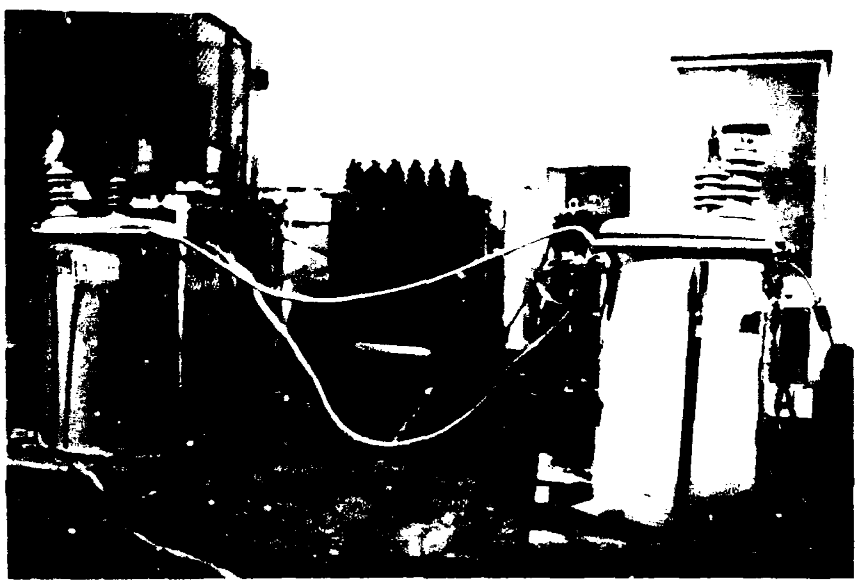


Figure C-4 24-kVA amorphous metal-core transformers undergoing design tests at transformer plant.

Figure C-5. Infrared scanning test of 25-kVA amorphous metal-core transformer (left) and a 25-kVA silicon-steel transformer (right).

Figure C-6. General Electric engineers inspecting the bottom frame and containment box of a 25-kVA amorphous metal-core transformer for amorphous metal particles.

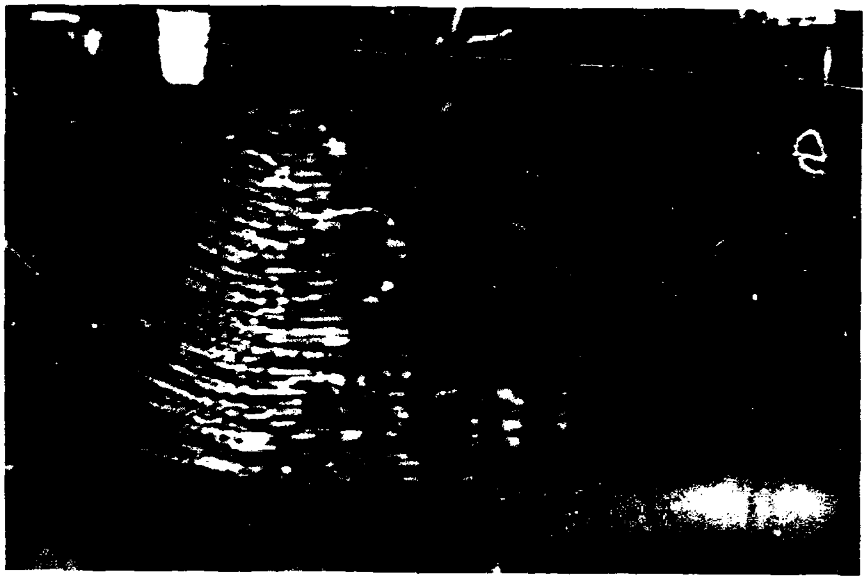


Figure C-7. Several amorphous metal particles found on the core of a 25-kVA amorphous metal-core transformer.

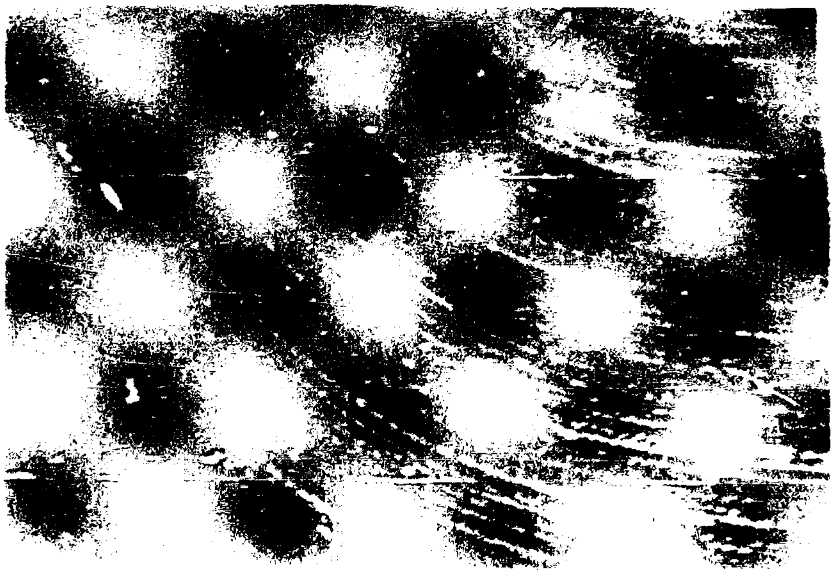


Figure C-8. Amorphous metal chip on the core of a 25-kVA amorphous metal-core transformer discovered during Phase I testing.

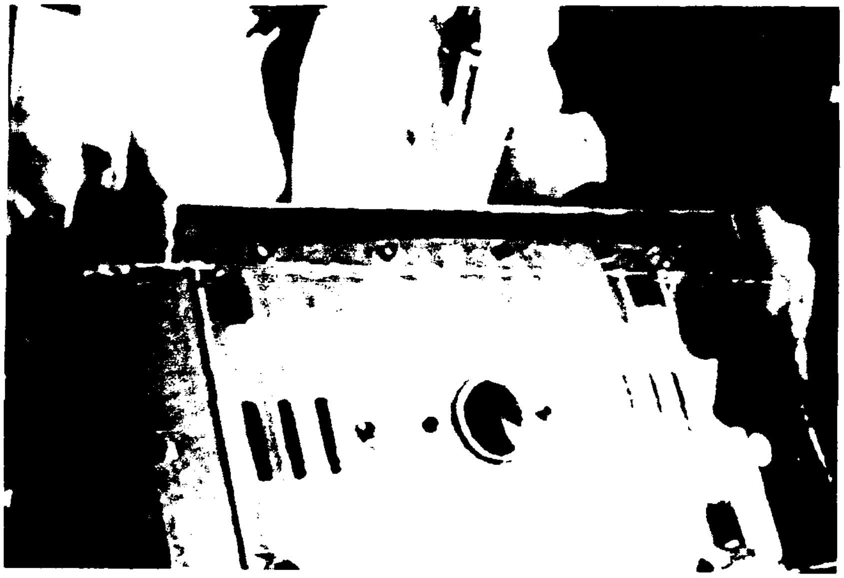


Figure C-9. Several amorphous metal particles found in the bottom frame of a 25-kVA amorphous metal-core transformer during Phase I testing.

Figure C-10. An amorphous metal particle found in the bottom frame of a 25-kVA amorphous metal-core transformer.

Figure C-11. A 25-kVA amorphous metal-core transformer undergoing a 4-foot drop test.

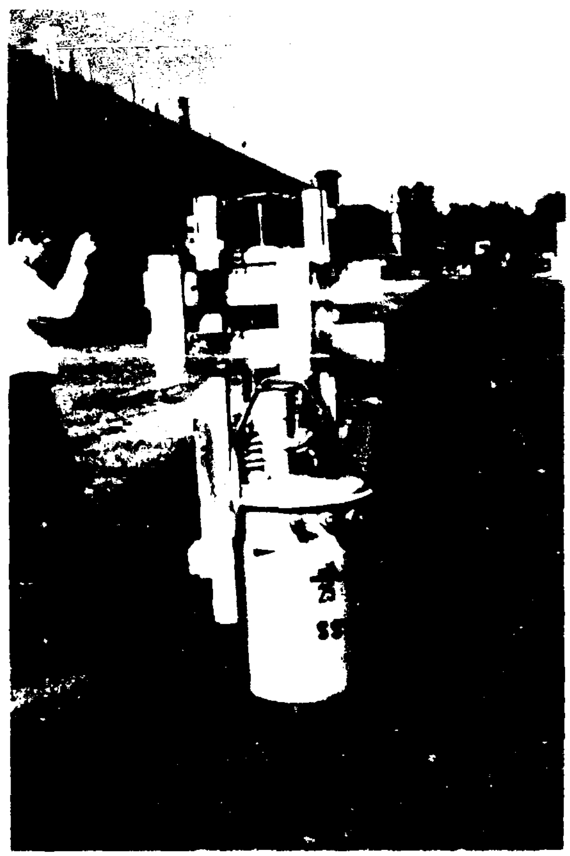


Figure C-12. A 25-kVA amorphous metal-core transformer after a 4-foot drop test.

Appendix D

REVISED PHASE I SATURATION TEST DATA

TABLE A.1.11.1 NO-LOAD LOSS SATURATION DATA
FOR TOP OIL TEMPERATURE STABILIZED AT 21.7 DEG C WITH NO LOAD
AMORPHOUS METAL TRANSFORMER P217061-YZA

FLUX VOLTS	%RATED FLUX VOLTS	RMS VOLTS	CURRENT	% RATED EXCITING CURRENT	WATTS
20.000	16.700	20.400	0.060	0.029	1.100
40.000	33.300	40.200	0.079	0.038	3.000
60.000	50.000	60.100	0.096	0.046	5.400
80.000	66.700	80.000	0.113	0.054	8.400
90.000	75.000	90.000	0.127	0.061	10.300
100.000	83.300	100.100	0.153	0.073	12.500
110.000	91.700	110.000	0.210	0.101	15.200
120.000	100.000	120.000	0.378	0.181	18.700
125.000	104.200	125.100	0.571	0.274	20.700
130.000	108.300	130.100	0.957	0.459	22.800
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE A.1.11.2 NO-LOAD LOSS SATURATION DATA
FOR TOP OIL TEMPERATURE STABILIZED AT 41 DEG C AFTER [illegible]
AT 50% OF NAMEPLATE RATING
AMORPHOUS METAL TRANSFORMER P21[illegible]A1-[illegible]A

FLUX VOLTS	%RATED FLUX VOLTS	RMS VOLTS	CURRENT	% RATED EXCITING CURRENT	WATTS
20.000	16.700	20.500	0.068	0.033	1.2[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	50.000	[illegible]	0.094	[illegible]	[illegible]
80.000	66.700	80.000	0.110	0.053	8.200
[illegible]	75.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
110.000	91.700	110.000	0.217	0.104	14.900
[illegible]	[illegible]	120.100	0.404	0.194	18.4[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE A.1.11.3 NO-LOAD LOSS SATURATION DATA
FOR TOP OIL TEMPERATURE STA[illegible]
AT 100% OF NAMEPLATE RATING
AMORPHOUS METAL TRANSFORMER PC17[illegible]1-Y2A

FLUX VOLTS	%RATED FLUX VOLTS	RMS VOLTS	CURRENT	% RATED EXCITING CURRENT	WATTS
20.000	16.700	20.400	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
80.000	66.700	80.100	0.107	0.051	7.500
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]152	[illegible]	[illegible]
110.000	91.7[illegible]	110.100	[illegible]229	0.109	14.[illegible]
[illegible]	[illegible]	119.9[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]371	[illegible]

TABLE A.1.11.4 NO-LOAD LOSS SATURATION DATA
FOR TOP OIL TEMPERATURE STABILIZED AT [illegible] DEG C AFTER [illegible]
AT [illegible]% OF NAMEPLATE RATING
AMORPHOUS METAL TRANSFORMER [illegible]

%RATED FLUX VOLTS	FLUX VOLTS	RMS VOLTS	CURRENT	% RATED EXCITING CURRENT	WATTS
20.000	15.700	[illegible]	0.061	0.029	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
80.000	66.700	80.100	0.106	0.051	8.300
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
110.000	91.700	109.800	0.262	0.126	14.400
120.000	100.000	120.000	0.654	0.314	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE A.1.11.5 NO-LOAD LOSS SATURATION DATA
FOR TOP OIL TEMPERATURE STABILIZED AT 22.7 DEG C WITH NO LOAD

STANDARD SILICON STEEL TRANSFORMER P 239216-YOD

FLUX VOLTS	%RATED FLUX VOLTS	RMS VOLTS	CURRENT	% RATED EXCITING CURRENT	WATTS
20.000	16.700	20.400	0.197	0.095	2.900
40.000	33.300	40.100	0.242	0.116	7.900
60.000	50.000	60.000	0.299	0.144	15.300
80.000	66.700	80.000	0.361	0.173	25.500
90.000	75.000	90.100	0.402	0.193	31.900
100.000	83.300	99.900	0.463	0.222	38.500
110.000	91.700	109.900	0.618	0.297	45.700
120.000	100.000	120.000	1.829	0.878	68.800
125.000	104.200	125.200	4.447	2.135	72.600
130.000	108.300	131.000	7.611	3.653	[illegible]
132.000	110.000	133.900	8.537	4.098	[illegible]

TABLE A.1.11.6 NO-LOAD LOSS SATURATION DATA
FOR TOP OIL TEMPERATURE STABILIZED AT 47.8 DEG C AFTER LOADING AT
50% OF NAMEPLATE RATING

STANDARD SILICON STEEL TRANSFORMER P 239216-YOB

FLUX VOLTS	%RATED FLUX VOLTS	RMS VOLTS	CURRENT	% RATED EXCITING CURRENT	WATTS
20.000	16.700	20.300	0.179	0.086	2.600
40.000	33.300	40.300	0.243	0.117	7.800
60.000	50.000	60.200	0.300	0.144	15.200
80.000	66.700	80.000	0.353	0.169	24.900
90.000	75.000	90.100	0.399	0.191	31.000
100.000	83.300	100.000	0.438	0.210	38.400
110.000	91.700	110.100	0.623	0.299	48.800
120.000	100.000	120.100	1.979	0.950	68.500
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE A.1.11.7 NO-LOAD LOSS SATURATION DATA
FOR TOP OIL TEMPERATURE STABILIZED AT 78 DEG C AFTER [illegible]
100% OF NAMEPLATE RATING

STANDARD SILICON STEEL TRANSFORMER P [illegible]

FLUX VOLTS	%RATED FLUX VOLTS	RMS VOLTS	CURRENT	% RATED EXCITING CURRENT	WATTS
20.000	16.700	20.400	[illegible]	[illegible]	[illegible]
40.[illegible]	[illegible].300	40.[illegible]	[illegible]	[illegible]	[illegible]
60.000	50.000	60.200	0.789	0.139	14.600
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
100.000	83.300	100.000	0.457	0.217	37.700
[illegible]	91.700	110.100	0.629	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE A.1.11.8 NO-LOAD LOSS SATURATION DATA
FOR TOP OIL TEMPERATURE STABILIZED AT 128 DEG C AFTER LOADING AT
150% OF NAMEPLATE RATING

STANDARD SILICON STEEL TRANSFORMER P 279216-YOB

FLUX VOLTS	%RATED FLUX VOLTS	RMS VOLTS	CURRENT	% RATED EXCITING CURRENT	WATTS
20.000	16.700	20.300	0.156	0.075	2.200
40.000	33.300	40.100	0.218	0.105	6.900
60.000	50.000	60.100	0.277	0.133	13.900
80.000	66.700	80.100	0.340	0.163	23.500
90.000	75.000	90.100	0.382	0.183	29.500
100.000	83.300	100.000	0.450	0.216	36.700
110.000	91.700	110.000	0.649	0.312	46.500
120.000	100.000	120.100	2.494	1.197	66.800
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

AMORPH EXCITG CURRENT NO LOAD	SILICON EXCITG CURRENT NO LOAD	SI/AM EXCITG CURRENT NO LOAD	AMORPH NO-LOAD LOSS WATTS	SILICON NO-LOAD LOSS WATTS	AM/SI NO-LOAD LOSS WATTS	%RATED FLUX VOLTS
0.060	0.197	3.283	1.100	2.900	0.379	16.700
0.079	0.242	3.063	3.000	7.900	0.380	33.300
0.096	0.299	3.115	5.400	15.300	0.353	50.000
0.113	0.361	3.195	8.400	25.500	0.329	66.700
0.127	0.402	3.165	10.300	31.900	0.323	75.000
0.153	0.463	3.026	12.500	38.500	0.325	83.300
0.210	0.618	2.943	15.200	45.700	0.333	91.700
0.378	1.829	4.839	18.700	68.800	0.272	100.000
0.571	4.447	7.788	20.700	72.600	0.285	104.2[illegible]
0.957	7.611	7.953	22.800	138.600	0.165	108.300
1.848	8.537	4.620	25.400	163.800	0.155	112.500

AMORPH EXCITG CURRENT 50% LOAD	SILICON EXCITG CURRENT 50% LOAD	SI AM EXCITG CURRENT 50% LOAD	AMORPH NO-LOAD LOSS WATTS	SILICON NO-LOAD LOSS WATTS	AM-SI NO-LOAD LOSS WATTS	[illegible] VOLTS
0.068	0.179	2.632	1.2[illegible]	2.[illegible]	[illegible].4[illegible]	1[illegible]
0.080	0.247	3.076	3.1[illegible]	7.80[illegible]	[illegible]	33.[illegible]
0.094	0.[illegible]	3.191	5.[illegible]	15.[illegible]	[illegible]	[illegible]
0.11[illegible]	0.757	3.219	8.[illegible]	23.9[illegible]	[illegible]	[illegible]
0.12[illegible]	0.399	3.1[illegible]	1[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.21[illegible]	0.521	2.571	14.[illegible]	40.[illegible]	[illegible]	41.[illegible]
[illegible]	1.579	4.[illegible]	18.[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	7.733	[illegible]	[illegible]	179.1[illegible]	[illegible]	[illegible]
[illegible]	3.8[illegible]	[illegible]	[illegible]	1[illegible]	[illegible]	1[illegible]

AMORPH EXCITG CURRENT 100%LOAD	SILICON EXCITG CURRENT 100%LOAD	SI/AM EXCITG CURRENT 100%LOAD	AMORPH NO-LOAD LOSS WATTS	SILICON NO-LOAD LOSS WATTS	[illegible] NO-LOAD LOSS WATTS	[illegible] VOLTS
0.063	0.172	2.730	1.200	2.300	0.527	16.[illegible]
0.075	0.230	3.067	2.800	7.400	0.378	33.300
0.089	0.289	3.247	5.100	14.600	0.349	50.[illegible]
0.107	0.350	3.271	7.900	24.200	0.32[illegible]	66.[illegible]
0.123	0.392	3.187	9.700	30.300	0.320	75.[illegible]
0.152	0.457	[illegible]	11.800	37.700	[illegible]	[illegible]
0.228	0.629	2.759	14.600	47.700	0.306	91.[illegible]
0.468	2.096	4.479	18.000	67.300	0.267	100.000
[illegible]	5.200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.459	7.800	5.346	22.100	143.000	0.155	106.300
4.785	9.028	1.887	26.700	176.600	0.149	112.5[illegible]

AMORPH EXCITG CURRENT 150%LOAD	SILICON EXCITG CURRENT 150%LOAD	SI/AM EXCITG CURRENT 150%LOAD	AMORPH NO-LOAD LOSS WATTS	SILICON NO-LOAD LOSS WATTS	AM/SI NO-LOAD LOSS WATTS	%RATED FLUX VOLTS
0.061	0.156	2.557	1.100	2.200	0.500	16.700
0.074	0.218	2.946	3.000	6.900	0.435	33.300
0.086	0.277	3.221	5.400	13.900	0.388	50.000
0.106	0.340	3.208	8.300	23.500	0.353	66.700
0.124	0.382	3.081	9.900	29.500	0.336	75.000
0.160	0.450	2.813	11.700	36.700	0.319	83.300
0.262	0.649	2.477	14.400	46.500	0.310	91.700
0.654	2.494	3.813	17.700	66.800	0.265	100.000
1.218	6.325	5.193	19.700	94.500	0.208	104.200
3.537	8.514	2.407	23.100	152.200	0.152	108.300
8.956	9.478	1.058	79.900	174.500	0.458	112.500

Appendix E

GENERAL ELECTRIC COMPANY TEST REPORT NO. 88-AMT-001

Amorphous Metal Distribution Transformer 3-Foot Drop Test

(Printed by permission of General Electric Company, July 1989, distribution unlimited)

GE Transformer
Business

February 10, 1988

Mr. Guy V. Urata
Naval Civil Engineering Lab
Code L72
Port Hueneme, CA 93043-5003

Subject: **Amorphous Metal Distribution Transformer,**
3-Ft. Drop Test Report 88-AMT-001

Dear Mr. Urata:

Per Mr. Westhaus' request, I've prepared the subject test report 88-AMT-001, which documents the 3-ft. drop test on three GE Amorphous Metal Cored Distribution Transformers. This test was performed at the GE Distribution Transformer Plant, Hickory, N. C. on April 22, 1987. Mr. John Franchi, of NCEL witnessed all test operations, as well as post drop test examination of the interior assemblies. In addition, Mr. Robert Wright of NCEL took both still photos and video tapes of these operations.

We are very pleased on the outcome of this 3-ft. drop test. It verified once and for all the structural integrity of GE's amorphous metal cored distribution transformers. Please call me if you have any questions.

Sincerely yours,

Albert C. Lee
Senior Development Engineer

l/021088-1

p.s.: Computer tabulation of initial factory test results on the three transformers is also attached.

cc: Randy Westhaus
Advance Technology, Inc.
751 Daily Drive, Suite 220
Camarillo, CA 93010

John Franchi
Naval Civil Engineering Lab
Code L72
Port Hueneme, CA 93043-5003

R. M. Carr-GE Company
9350 Flair Drive
El Monte, CA 91731

3/18/87 LOSSES FILE LISTING BY CUSTOMER --- PAGE

Initial Factory Test

TS NUMBER	SER NUMBER	ACTUAL NOLOAD	ACTUAL LOAD	ACTUAL TOTAL	IZ	EXC CURR	TEST TEMP	TEST DATE	SHIP	TALLY
3601ADOA25LAO	P217059	17.90	319.20	337.10	2.46	.11	0024	1210	121786	
3601ADOA25LAO	P217060	15.21	317.40	333.60	2.46	.31	0026	1217	121786	
3601ADOA25LAO	P217061	17.20	312.10	329.30	2.46	.30	0026	1216	121786	
TSNO TOTAL		17.10	316.23	333.33	2.46	.24				3

3/31/87 LOSSES FILE LISTING BY CUSTOMER --- PAGE 1

Initial Factory Test

TS NUMBER	SER NUMBER	ACTUAL NOLOAD	ACTUAL LOAD	ACTUAL TOTAL	IZ	EXC CURR	TEST TEMP	TEST DATE	SHIP	TALLY
3601ADOA25LAO	P265882	13.60	315.80	329.40	2.49	.15	0022	0323	COMPLT	
3601ADOA25LAO	P265884	13.70	316.10	329.80	2.50	.18	0023	0323	COMPLT	
3601ADOA25LAO	P265885	13.60	319.50	333.10	2.49	.17	0022	0323	COMPLT	
3601ADOA25LAO	P217059	17.90	319.20	337.10	2.46	.11	0024	1210	121786	
3601ADOA25LAO	P217060	16.20	317.40	333.60	2.46	.31	0026	1217	121786	
3601ADOA25LAO	P217061	17.20	312.10	329.30	2.46	.30	0026	1216	121786	
TSNO TOTAL		15.36	316.68	332.05	2.47	.20				6

9/02/87 LOSSES FILE LISTING BY TS NUMBER (EASYLOSS BYTSNUM) PAGE 1

Post 3-ft. Drop Test

TS NUMBER	SERIAL NUMBER	NO-LOAD LOSS-TST	LOAD-LOSS TEST	TOT-LOSS TEST	%IMP TEST	%EXC TEST	TEST TEMP	TEST DATE	FINISH DATE	SHIP DATE	TALLY
3601ADOA25LAO	P217059	17.90	319.20	337.10	2.46	.11	24	861210	861212	861217	
	P217060	16.20	317.40	333.60	2.46	.31	26	861217	861217	861217	
	P217061	17.60	312.30	329.90	2.47	.28	27	870422	861217	861217	
	P265882	13.90	314.80	328.70	2.49	.25	27	870422	870324		
	P265883	13.60	316.50	330.10	2.47	.21	22	870421	870402		
	P265884	14.10	311.20	325.30	2.49	.24	22	870421	870324		
	P265885	13.60	312.90	326.50	2.48	.23	28	870422	870324		
3601ADOA25LAO		15.27	314.90	330.17	2.47	.23	25				7

GENERAL ELECTRIC

DISTRIBUTION TRANSFORMER BUSINESS DEPARTMENT

Test Record

Subject	Amorphous Metal Cored Distribution Transformers	**Report Number** 88-AMT-001
Title	Static Drop Test, 25 kVA	**Date** 2/8/88

Object To confirm the structural integrity of amorphous metal cores used in distribution transformers by dropping them vertically from a height of three ft. onto a concrete pavement. This DROP TEST is considered as a DESTRUCTIVE TEST.

Test Equipment Pole-type distribution transformers per GE TS3601A00A25LA0 with voltage ratings of 4160/7200Y-120/240. S/N P217061(1), P265882(2) and P265885(2). All three transformers completed a trucking round trip between Hickory, N. C. and Naval Civil Engineering Lab (NCEL) in Port Hueneme, CA (A total shipping distance of ~5000 miles). Notes: 1) core has no encapsulant at joint area; 2) core has encapsulant at joint area.

Test Method DROP TEST was conducted at Hickory, N. C. on April 22, 1987. It consists of lifting the transformer to a three foot height and hanging in air by means of a steel wire. The wire was then cut and allowed the transformer to drop squarely onto the concrete pavement. See photos 1 & 2.

After completion of the 5000-mile shipping distance and after the DROP TEST, each transformer was untanked, and the interior assembly was examined for any sign of damage and any presence of amorphous metal particles and chips.

Each transformer was given a commercial electrical test in the factory before and after the DROP TEST. Tests were also performed in the Dev. Lab.

Results

1. Elect.*	S/N P217061				S/N P265882				S/N P265885			
	Factry Test		Lab Test		Factry Test		Lab Test		Factry Test		Lab Test	
	Watts	Amps	Watts	Amps	Watts	Amps	Watts	Amps	Watts	Amps	Watts	Amps
Before:	18.7	.29	18.2	.37	13.0	.25	14.5	.27	14.3	.27	14.5	.34
After:	17.6	.29	18.1	.41	13.9	.26	14.2	.28	13.6	.24	14.1	.32
Change%	-5.6	-0-	+0.55	+11.1	+6.9	+4.0	-2.1	+3.0	-4.9	+11.1	-2.8	-5.9

2. Mech.**	S/N P217061	S/N P265882	S/N P265885
a.	Tank bottom "bulged"	Tank bottom "bulged"	Tank bottom "bulged"
b.	Top clamp bent	Top clamp bent	Top clamp bent
c.	---	H1 HV bushing broken	---
3. AM Metal - Particles & Chips			
a.	None in oil	None in oil	None in oil
b.	7 small chips inside bottom chip containment box.	4 small chips inside bottom chip containment box.	1 small chip inside bottom chip containment box

* (See computer printouts) ** (See Photos 3,4 & 5)

Conclusions (1) Amorphous metal core, with & w/o encapsulant over the cut joint area, remains structurally sound after a 3-ft. drop; (2) Electrical performance remains essentially unchanged after a 3-ft. destructive DROP TEST; (3) The effectiveness of chip containment box was demonstrated; and (4) in spite of tank deformation and clamp damage, all 3 transformers remain functionally good (except broken HV bushing must be replaced).

GENERAL ELECTRIC CO
P. O. BOX 2188
HICKORY, NC 28601

ENGINEER Albert C. Lee TITLE Sr. Dev. Eng.

Photo #1 GENERAL ELECTRIC
AM Distribution Transformer
Ready for a 3-Ft. Drop Test

Photo #2 GENERAL ELECTRIC
AM Distribution Transformer
Being Dropped from a 3-Ft. Height

Photo #3 Bottom of Tank "Bulged" After a 3-Ft. Drop. Note imprint by tank on concrete pavement.

Photo #4 One of the High Voltage bushings (H1) broke after impact.

Photo #5 Interior assembly untanked for examination. Note bent top clamp

Photo [illegible]

Photo [illegible]

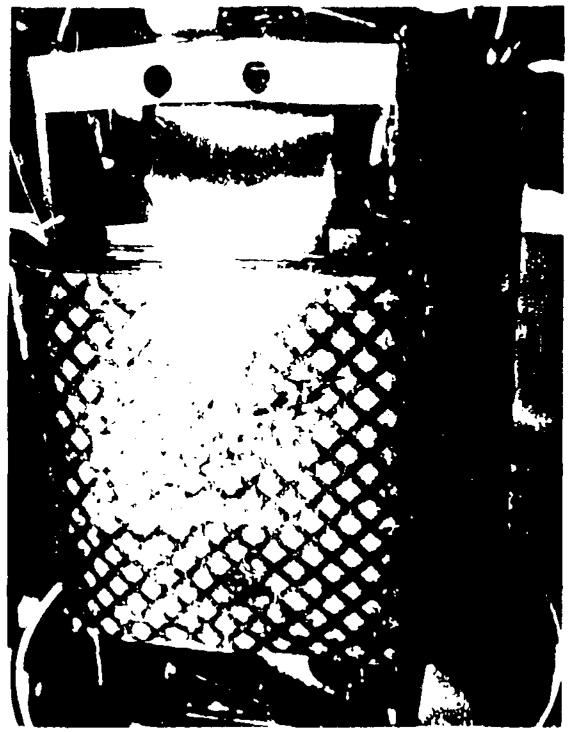


Photo #5

A. After 5000-mile Shipping Distance & Before 3-Ft. Drop Test

```
SER.NO. [illegible]  T.[illegible].NO. 3601ADOA[illegible]  KVA [illegible]  RATING 240 [illegible]

   BLUE QUAD                    DATE [illegible]   TIME [illegible]

                    FLUXV    RMSV    AMPS    WATTS

EXCITATION          240.3    243.[illegible]   [illegible].29    [illegible]    RATIO [illegible]    [illegible]

INDUCE                       480.[illegible]   [illegible]    [illegible]                         [illegible]

IMPEDANCE                    [illegible]   [illegible]   [illegible]   TEMP [illegible]   [illegible]
   TOTAL WATTS @ 85C                          [illegible]   [illegible]   [illegible]

LV HIPOT KV                  10.0                                                  [illegible]

HV HIPOT KV                  25.9                                                  [illegible]

IMPULSE KV  H1 = [illegible]   X3 = 0.0   X1 = [illegible]   H1 PAR = [illegible]   [illegible]

CB LEFT   AMPS =   0.0   MAIN =   0.0   TEMP =   0.0   LIGHT = [illegible]     NONE

FAILURE MODE                 PASSED UNIT
```

B. After 3-Ft. Drop Test

```
SER.NO. P217061-YZA  T.S.NO. 3601ADOA25LA0L  KVA  25  RATING 240 [illegible]

   WHITE QUAD                   DATE 22-APR-87   TIME 16:[illegible]:[illegible]

                    FLUXV    RMSV    AMPS    WATTS

EXCITATION          240.6    243.5   0.29    17.6    RATIO = 1[illegible].[illegible]   [illegible]

INDUCE                       480.3   0.85    25.7                           [illegible]

IMPEDANCE                    [illegible]  103.9[illegible]  [illegible]   TEMP [illegible]   [illegible]
   TOTAL WATTS @ 85C                         329.[illegible]   [illegible]   [illegible]

LV HIPOT KV                  10.0                                           [illegible]

HV HIPOT KV                  [illegible]6.0                                 [illegible]

IMPULSE KV  H1 = 93.[illegible]   X3 = 0.0   X1 = 0.0   H1 PAR = [illegible]   [illegible]

CB LEFT   AMPS =   0.0   MAIN =   0.0   TEMP = [illegible]   LIGHT = [illegible]   NONE

FAILURE MODE                 PASSED UNIT
```

A. <u>After 5000-Mile Shipping Distance & Before 3-Ft. Drop Test</u>

SER.NO. [illegible]-YRB T.S.NO. 3601ADOA25LAOL KVA 25 RATING [illegible]

WHITE QUAD DATE 21-APR-87 TIME [illegible]:30:13

	FLUXV	RMSV	AMPS	WATTS		
EXCITATION	241.0	244.1	0.25	13.0	RATIO = [illegible]	[illegible]
INDUCE		482.[illegible]	0.89	16.[illegible]		[illegible]
IMPEDANCE		5.72	104.35	25[illegible]	TEMP = [illegible]	[illegible]
TOTAL WATTS @ 85C				318.[illegible]	% IMP = [illegible]	
LV HIPOT KV		10.0				[illegible]
HV HIPOT KV		26.0				PASS

IMPULSE KV H1 = 92.8 X3 = 0.0 X1 = 0.0 H1 PAR = [illegible] [illegible]

CB LEFT AMPS = 0.0 MAIN = 0.0 TEMP = 0.0 LIGHT = [illegible] NONE

FAILURE MODE PASSED UNIT

B. <u>After 3-Ft. Drop Test</u>

SER.NO. P265882-YRB T.S.NO. 3601ADOA25LAOL KVA 25 RATING 240/ 416

WHITE QUAD DATE 22-APR-87 TIME 15:43:40

	FLUXV	RMSV	AMPS	WATTS		
EXCITATION	240.6	243.5	0.26	13.9	RATIO = [illegible].35	[illegible]
INDUCE		4[illegible]9.6	0.89	19.6		[illegible]
IMPEDANCE		5.73	103.97	[illegible]	TEMP = [illegible]	[illegible]
TOTAL WATTS @ 85C				328.7	% IMP = [illegible]	
LV HIPOT KV		10.0				[illegible]
HV HIPOT KV		25.9				[illegible]

IMPULSE KV H1 = 92.8 X3 = 0.0 X1 = 0.0 H1 PAR = 0.0 [illegible]

CB LEFT AMPS = 0.0 MAIN = 0.0 TEMP = 0.0 LIGHT = 0.0 [illegible]

FAILURE MODE PASSED UNIT

A. After 5000-Mile Shipping Distance & Before 3-Ft. Drop Test

SER.NO. P265885-YRB T.S.NO. 3601ADOA25LAOL KVA 25 RATING 240/ 4160

RED QUAD DATE 21-APR-87 TIME 12:31:31

	FLUXV	RMSV	AMPS	WATTS		
EXCITATION	241.0	244.0	0.27	14.3	RATIO = 17.36	PASS
INDUCE		480.1	0.88	22.5		PASS
IMPEDANCE		5.71	103.69	254.0	TEMP = 22.[illegible]	PASS
TOTAL WATTS @ 85C				326.9	% IMP = [illegible]	
LV HIPOT KV		10.0				PASS
HV HIPOT KV		25.9				PASS

IMPULSE KV H1 = 92.7 X3 = 0.0 X1 = 0.0 H1 FAR = 0.0 PASS

CB RIGHT AMPS = 0.0 MAIN = 0.0 TEMP = 0.0 LIGHT = 0.0 NONE

FAILURE MODE PASSED UNIT

B. After 3-Ft. Drop Test

SER.NO. P265885-YRB T.S.NO. 3601ADOA25LAOL KVA 25 RATING 240/ 4160

GREEN QUAD DATE 22-APR-87 TIME 15:31:20

	FLUXV	RMSV	AMPS	WATTS		
EXCITATION	240.6	243.5	0.24	13.6	RATIO = 17.35	PASS
INDUCE		480.2	0.85	19.7		PASS
IMPEDANCE		5.71	104.00	259.9	TEMP = [illegible]	PASS
TOTAL WATTS @ 85C				326.5	% IMP = [illegible]	
LV HIPOT KV		10.0				PASS
HV HIPOT KV		25.9				PASS

IMPULSE KV H1 = 92.8 X3 = 0.0 X1 = 0.0 H1 FAR = 0.0 PASS

CB RIGHT AMPS = 0.0 MAIN = 0.0 TEMP = 0.0 LIGHT = 0.0 NONE

FAILURE MODE PASSED UNIT

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ARMY BELVOIR R&D CEN STRBE-AALO, Ft Belvoir, VA; STRBE-BLORE, Ft Belvoir, VA

ARMY CERL CERL-ES (DL Johnson), Champaign, IL; CERL-ESD (D Chu), Champaign, IL; Energy Sys Div, Champaign, IL; Library, Champaign, IL; CERL-EN, Champaign, IL

ARMY CORPS OF ENGRS A. Azares, Sacramento, CA

ARMY CRREL A. Iskandar, Hanover, NH; CRREL-EA, Hanover, NH

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ARMY EHA Dir, Env Qual, Aberdeen Proving Grnd, MD; HSE-RP-HG, Arberdeen Proving Grnd, MD; HSHB-EA-S, Aberdeen Proving Grnd, MD; HSHB-EW, Aberdeen Proving Grnd, MD; HSHB-ME-A, Aberdeen Proving Grnd, MD

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CBU 405, OIC, San Diego, CA; 411, OIC, Norfolk, VA

CG FOURTH MARDIV Base Ops, New Orleans, LA

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CINCUSNAVEUR London, UK

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COMFLEACT PWO, Kadena, Japan; PWO, Sasebo, Japan; SCE, Yokosuka, Japan

COMNAVACT PWO, London, UK

COMNAVAIRSYSCOM AIR-714, Washington, DC; Code 422, Washington, DC

COMNAVLOGPAC Code 4318, Pearl Harbor, HI

COMNAVMARIANAS Code N4, Guam

COMNAVRESFOR Code 08, New Orleans, LA; Code 823, New Orleans, LA

COMNAVSUPPFORANTARCTICA DET, PWO, Christchurch, NZ

COMOCEANSYS Pac, SCE, Pearl Harbor, HI

COMSUBDEVGRU ONE Ops Offr, San Diego, CA

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DIRSSP Tech Lib, Washington, DC

DOE INEL Tech Lib Reports Sta, Idaho Falls, ID

DTRCEN Code 2834, Annapolis, MD; Code 284, Annapolis, MD; Code 4111, Bethesda, MD; Code 42, Bethesda MD; Code 421.1, Bethesda, MD; Code 522, Annapolis, MD; Code 4120, Annapolis, MD

EPA Reg III Lab, Philadelphia, PA; Reg VIII, Lab, Denver, CO
ESSM Whse 12 (Bowman), Williamsburg, VA
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MARCORDIST 12, Code 4, San Francisco CA
MARCORPS FIRST FSSG, Engr Supp Offr, Camp Pendleton, CA
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MCRD PWO, San Diego, CA
MCRDAC M & L Div Quantico, VA; NSAP Rep, Quantico, VA; AROICC, Quantico, VA
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